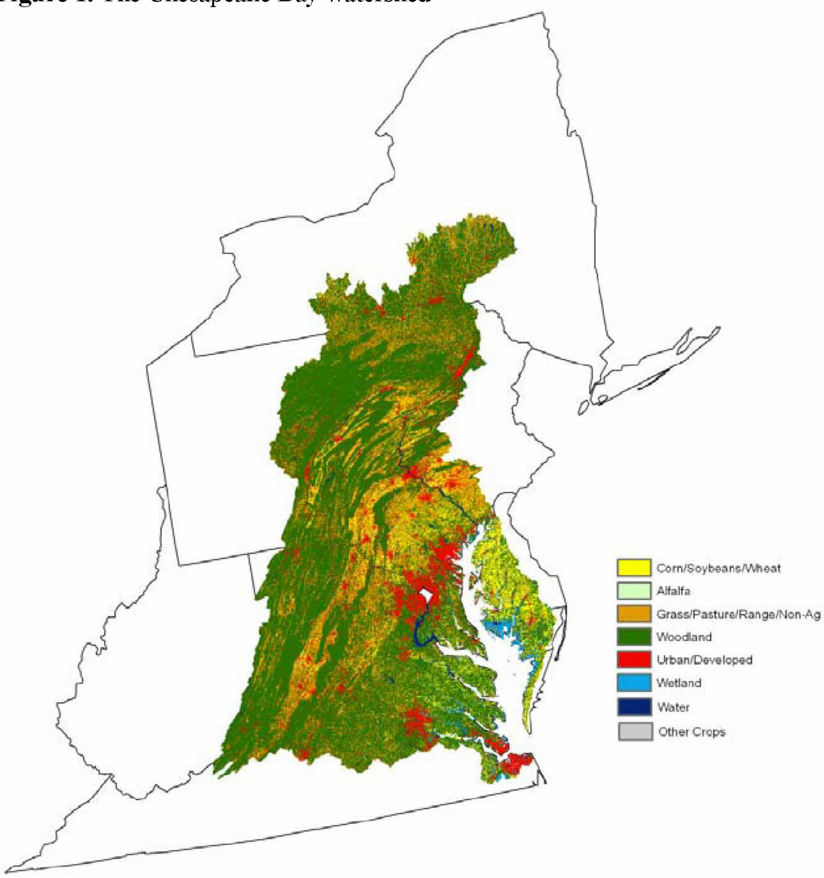
# Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Chesapeake Bay Region

## Summary of Findings

The Chesapeake Bay is the largest estuary in the United States. The Bay is about 200 miles long, and the Bay and its tributaries cover about 4,500 square miles of open water. The Chesapeake Bay watershed covers about 68,500 square miles in parts of six states (Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia) and the District of Columbia (fig. 1).

Agricultural land makes up less than 30 percent of the area of the watershed (10 percent cultivated cropland, and 18 percent pasture and hayland,). Forest land covers about 59 percent and urban land about 8 percent of the watershed. The balance of the area is in wetlands or is open water. The focus of the CEAP Chesapeake Bay study is on the 10 percent of the watershed that is cultivated cropland.

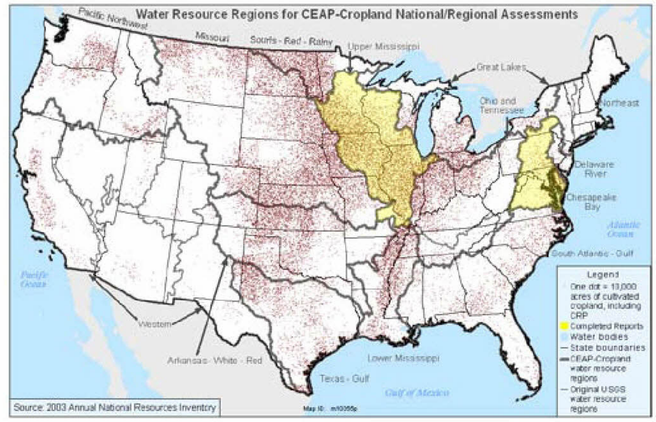
**Figure 1.** The Chesapeake Bay watershed



**River Basin Cropland Modeling Study Reports**
This series of reports will assess the effects of conservation practices on cultivated cropland, including land in long-term conserving cover.

*Upper Mississippi River Basin*
*Chesapeake Bay Watershed*
Delaware River Watershed
Ohio-Tennessee River Basins
New England Water Resource Region
South Atlantic-Gulf Water Resource Region
Missouri River Basin
Arkansas-White-Red River Basins
Texas Gulf Water Resource Region
Lower Mississippi River Basin
Great Lakes
Souris-Red-Rainy Water Resource Regions
Pacific Northwest and Western Water Resource Regions

Expect release of these reports through 2011.




**Methodology Used for the Cropland Assessments**
A simulation model was used to estimate the effects of conservation practices that were in use during the period 2003 to 2006. The NRCS National Resources Inventory, a statistical survey of conditions and trends in soil, water, and related resources on U.S. non-Federal land, provided the statistical framework. Information on farming activities and conservation practices was obtained from a farmer survey. Using those data, conservation practice effects were evaluated in terms of—

- reductions in losses of sediment, nutrients, and pesticides from farm fields;
- enhancement of soil quality through increases in soil organic carbon in the field; and
- reductions in instream loads of sediment, nutrients, and pesticides in the region's rivers and streams.

The physical process models used in this study are mathematical representations of the real world designed to estimate complex and varying environmental events and conditions. To estimate the effects of conservation practices, model simulation results were used to make *relative comparisons* between two model runs—one that includes conservation practices and one that excludes conservation practices. All other aspects of the input data and the model parameters were held constant.

The assessment includes conservation practices in use regardless of how or why they came to be in use. It is not restricted to only those practices associated with Federal conservation programs; the assessment also includes the conservation efforts of States, independent organizations, and individual landowners and farm operators.



**Difference between these two scenarios represents the benefits of the accumulation of conservation practices currently in place on the landscape.**

The U.S. Department of Agriculture initiated the Conservation Effects Assessment Project (CEAP) in 2003 to determine the effects and effectiveness of soil and water conservation practices on agricultural lands. The CEAP report *Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Chesapeake Bay Watershed* is the second is a series of studies covering the major river basins and water resource regions of the contiguous 48 United States. It was designed to quantify the effects of conservation practices commonly used on cultivated cropland in the Chesapeake Bay Watershed, evaluate the need for additional conservation treatment in the region, and estimate the potential gains that could be attained with additional conservation treatment.

## Study Findings

***Conservation practices work, but additional targeted investment will provide significant returns***

Good progress has been made on reducing sediment, nutrient, and pesticide losses from farm fields through conservation practice implementation in the Chesapeake Bay region, but a significant amount of conservation treatment remains to be done to reduce nonpoint agricultural sources of pollution.

- Use of soil erosion control practices is widespread, with most acres receiving some form of erosion control treatment. Nevertheless, about 26 percent of the cultivated cropland acres still have excessive sediment loss from fields and require additional erosion control practices.
- Significant improvement is still needed in nutrient management (proper rate, form, timing, *and* method of application) throughout the region. About 81 percent of the cultivated cropland acres require additional nutrient management to reduce the loss of nitrogen or phosphorus from fields.
- The most critical conservation concern in the region is loss of nitrogen through subsurface loss pathways, most of which eventually contribute to surface water loads. About 65 percent of cropped acres require additional nutrient management to address excessive levels of nitrogen loss in subsurface flow pathways, including surface and subsurface drainage systems. About 28 percent of cropped acres need treatment *only* for nitrogen loss in subsurface flows.
- About half of the cropped acres are critically under-treated, usually requiring treatment for multiple natural resource problems. These are the most vulnerable and/or under-treated acres with the highest losses in the region.
- Model simulations of additional conservation treatment show that nutrient loss from fields is within acceptable levels when soil erosion control practices are paired with management of rate, form, timing, and method of nutrient application that maximizes the availability of nutrients for crop growth while minimizing environmental losses.
- Treatment of erosion alone can exacerbate the nitrogen loss problem because reducing surface water increases infiltration and, therefore, movement of soluble nitrogen into subsurface flow pathways. A *suite* of practices that includes both soil erosion control and consistent nutrient management is required to simultaneously address soil erosion *and* nutrient loss.
- Conservation practices in the region have also been effective in reducing pesticide residues lost from fields as well as the associated environmental risk.

Cultivated cropland represents only about 10 percent of the land base in the Chesapeake Bay watershed. With the current level of conservation treatment, cultivated cropland delivers a disproportionate amount of sediment and nutrients to rivers and streams and ultimately to the Bay. Of the total loads delivered to rivers and streams from all sources, cultivated cropland is the source for 25 percent of the sediment, 27.5 percent of the phosphorus, and 32 percent of the nitrogen. Figure 2 shows the distribution of land uses within the Bay watershed, and figures 3 through 5 show the source of sediment, nitrogen, and phosphorus delivered to rivers and streams in the watershed.

Conservation practices in use on cultivated cropland within the watershed are responsible for reducing total loads delivered to the Bay (all sources) by 14 percent for sediment, 15 percent for phosphorus, and 15 percent for nitrogen.

**Figure 2.** Distribution of land use/cover types in the Chesapeake Bay watershed

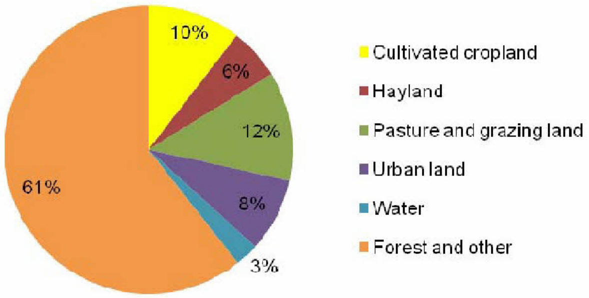



**Figure 3.** Percentage of average annual sediment loads delivered to rivers and streams in the Chesapeake Bay watershed, by source

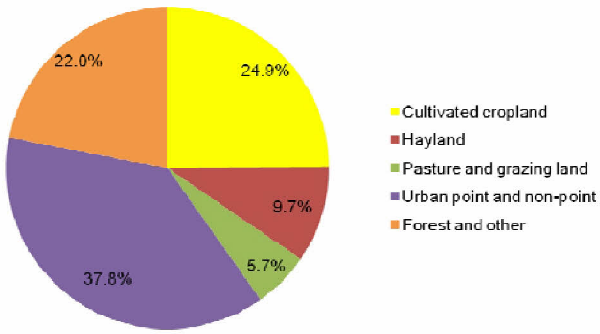



**Figure 4.** Percentage of average annual nitrogen loads delivered to rivers and streams in the Chesapeake Bay watershed, by source

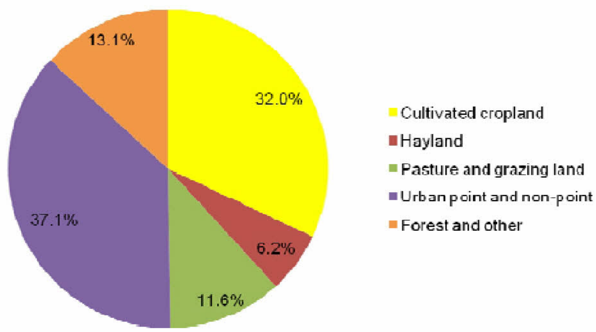
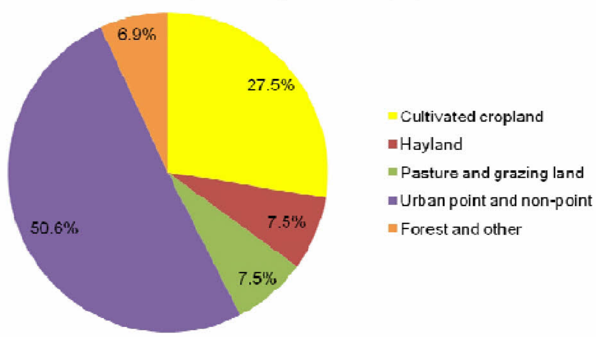



**Figure 5.** Percentage of average annual phosphorus loads delivered to rivers and streams in the Chesapeake Bay watershed, by source



### *Conservation treatment needs*

Of the 4.3 million acres of cultivated cropland in the Bay watershed, about 3.5 million are considered "under-treated," in that additional conservation practices are needed to reduce sediment and nutrient losses. Of this number, the 2 million acres that are most vulnerable to sediment or nutrient loss are considered "critically under-treated."

If all of the under-treated acres (81 percent of cropped acres) were fully treated with the appropriate soil erosion control and/or nutrient management practices, total loads delivered to the Bay (all sources) would be reduced from current levels by 7 percent for sediment (bringing loads from cultivated cropland down very close to "background levels"), 17 percent for phosphorus, and 16 percent for nitrogen.

Figures 6 through 8 show current and potential reductions in sediment, nitrogen, and phosphorus delivery to surface waters in the Chesapeake Bay watershed. In each figure, the top map shows delivery from cultivated cropland to rivers and streams and the bottom map shows delivery from all sources to the Bay itself.

These figures show conditions that would be expected if no conservation practices were in place (no-practice scenario), the current conservation condition (baseline), conservation treatment of the critical under-treated acres and all under-treated acres to reduce sediment and nutrient loss, and background levels.[1]

- **Figure 6:**
  - **Top map** shows that the use of conservation practices on cropland has reduced ***total sediment loads delivered to rivers and streams*** in the watershed by 64 percent from conditions that would be expected without conservation practices. It also shows that the application of additional conservation practices on all under-treated cultivated cropland acres could further reduce sediment delivery to rivers and streams by 84 percent from current levels.

  - **Bottom map** shows that the use of conservation practices on cropland has reduced ***total sediment loads delivered to Chesapeake Bay from all sources*** by 14 percent from conditions that would be expected without conservation practices. It also shows that the application of additional conservation practices on all under-treated cultivated cropland acres could further reduce sediment delivery to the Bay by 7 percent from current levels.

- **Figure 7:**
  - **Top map** shows that the use of conservation practices on cropland has reduced ***total nitrogen loads*** *delivered to rivers and streams* in the watershed by 36 percent from conditions that would be expected without conservation practices. It also shows that the application of additional conservation practices on all under-treated cultivated cropland acres could further reduce nitrogen delivery to rivers and streams by 53 percent from current levels.

  - **Bottom map** shows that the use of conservation practices on cropland has reduced ***total nitrogen loads delivered to Chesapeake Bay from all sources*** by 15 percent from conditions that would be expected without conservation practices. It also shows that the application of additional conservation practices on all under-treated cultivated cropland acres could further reduce nitrogen delivery to the Bay by 16 percent from current levels.

- **Figure 8:**
  - **Top map** shows that the use of conservation practices on cropland has reduced ***total phosphorus loads delivered to rivers and streams*** in the watershed by 43 percent from conditions that would be expected without conservation practices. It also shows that the application of additional conservation practices on all under-treated cultivated cropland acres could further reduce phosphorus delivery to rivers and streams by 71 percent from current levels.

  - **Bottom map** shows that the use of conservation practices on cropland has reduced ***total phosphorus loads delivered to Chesapeake Bay from all sources*** by 15 percent from conditions that would be expected without conservation practices. It

[1] "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional model scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

also shows that the application of additional conservation practices on all under-treated cultivated cropland acres could further reduce phosphorus delivery to the Bay by 17 percent from current levels.

**Figure 6.** Sediment

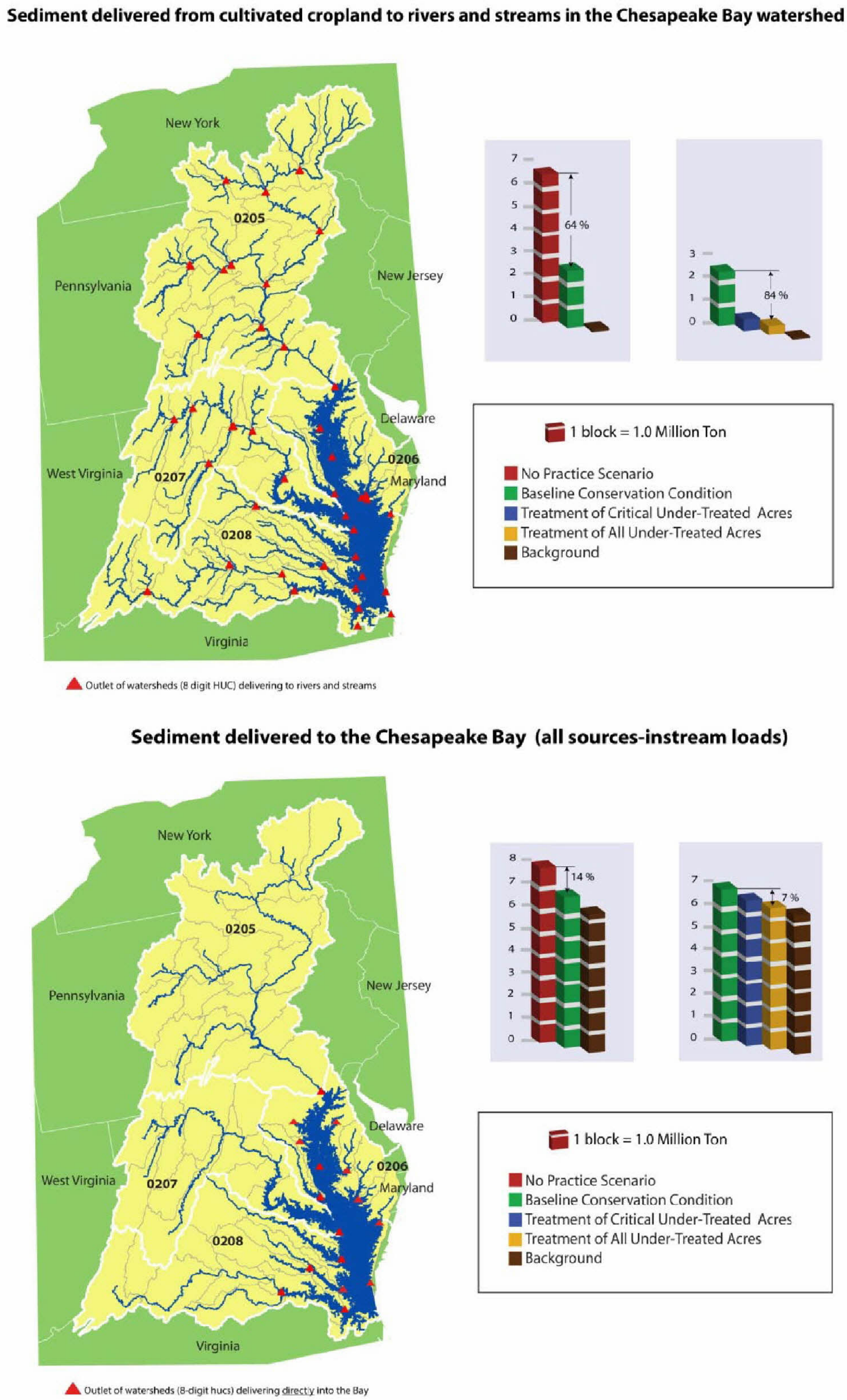





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**Figure 7.** Nitrogen

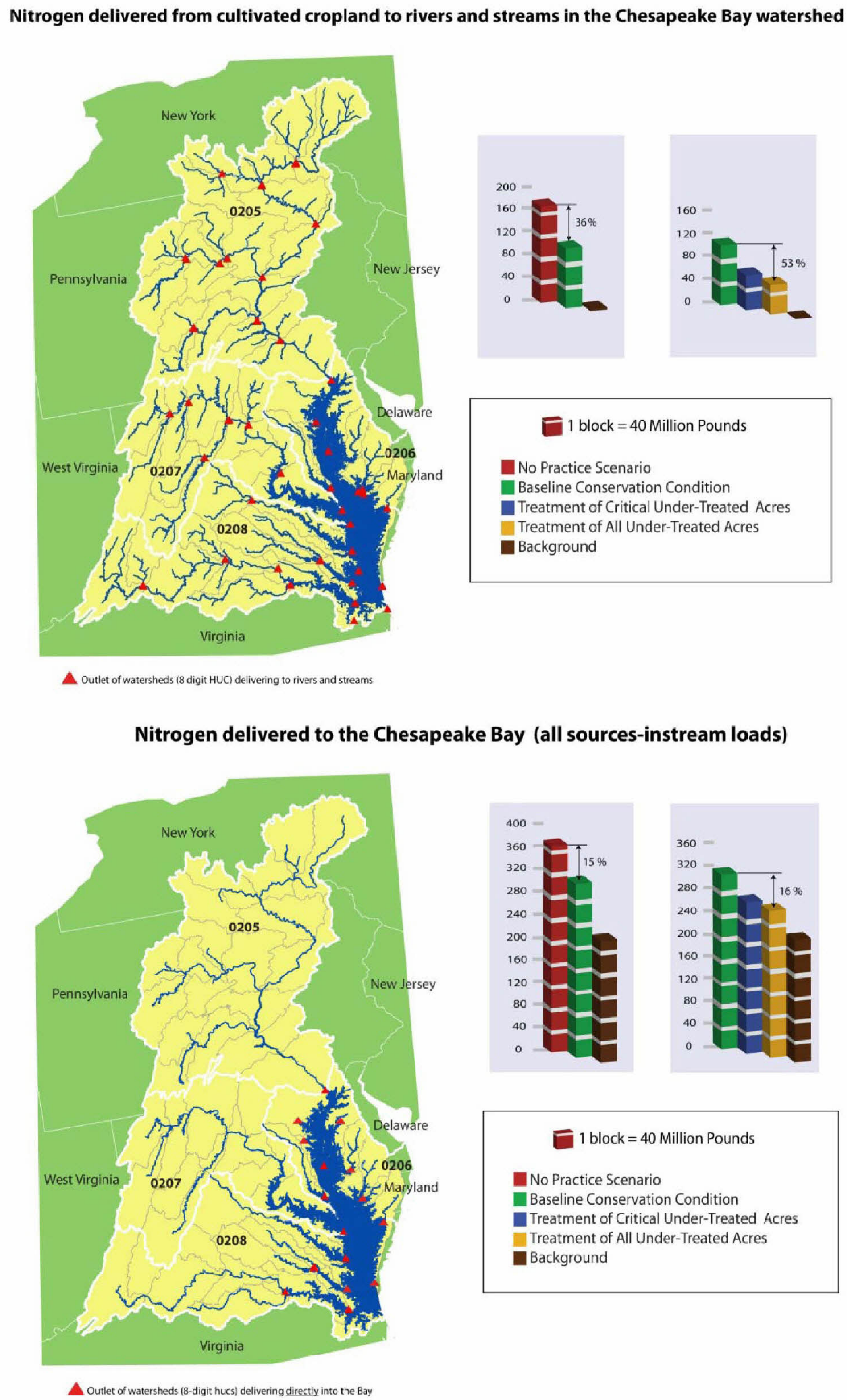
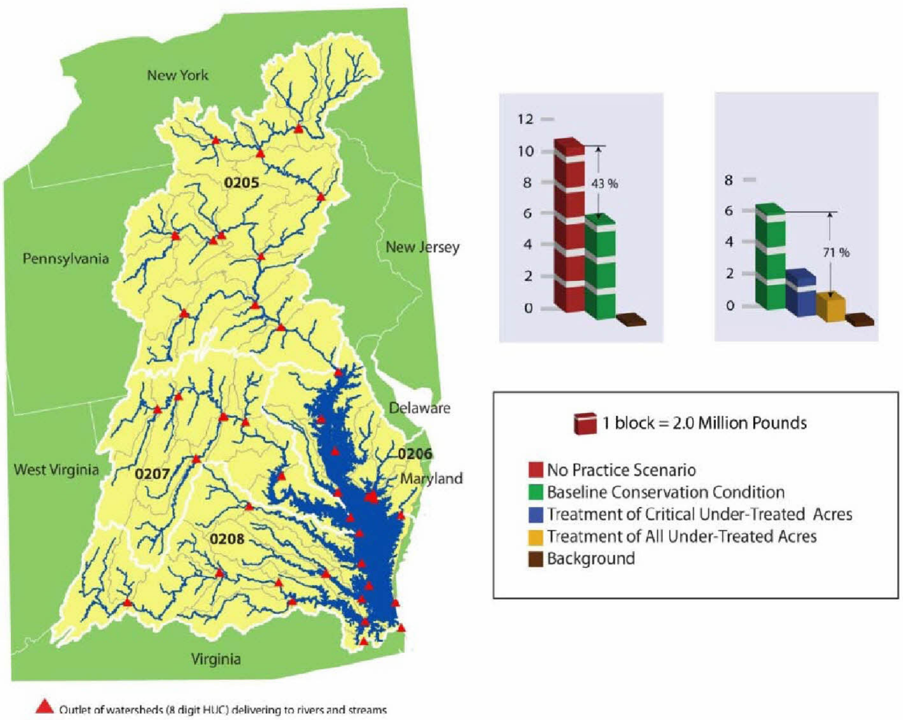
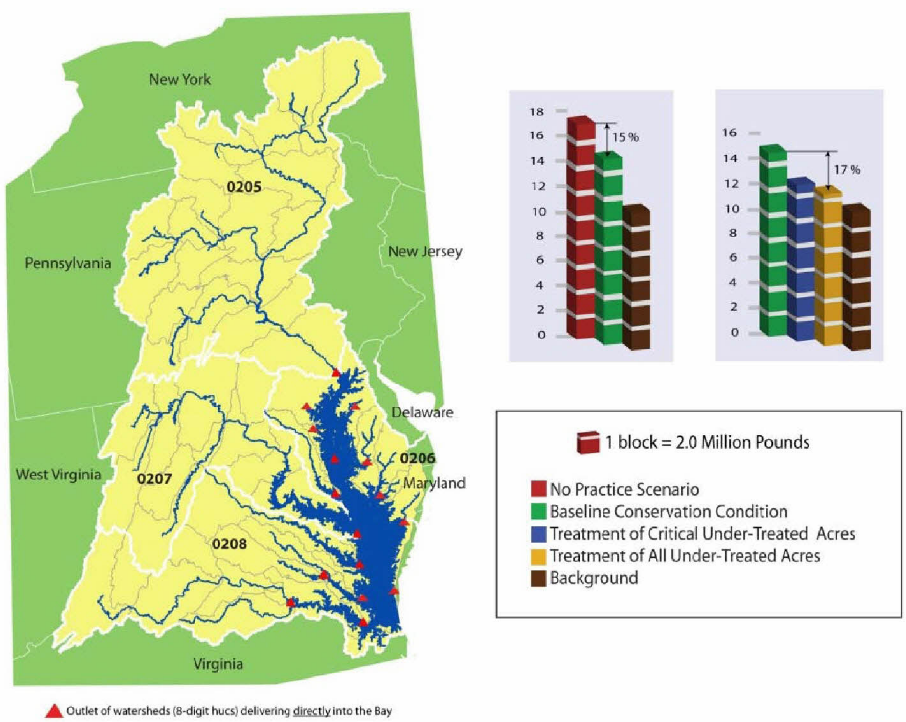


**Figure 8.** Phosphorus

**Phosphorus delivered from cultivated cropland to rivers and streams in the Chesapeake Bay watershed**




**Phosphorus delivered to the Chesapeake Bay (all sources-instream loads)**



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United States Department of Agriculture
Natural Resources Conservation Service

Conservation Effects
Assessment Project (CEAP)

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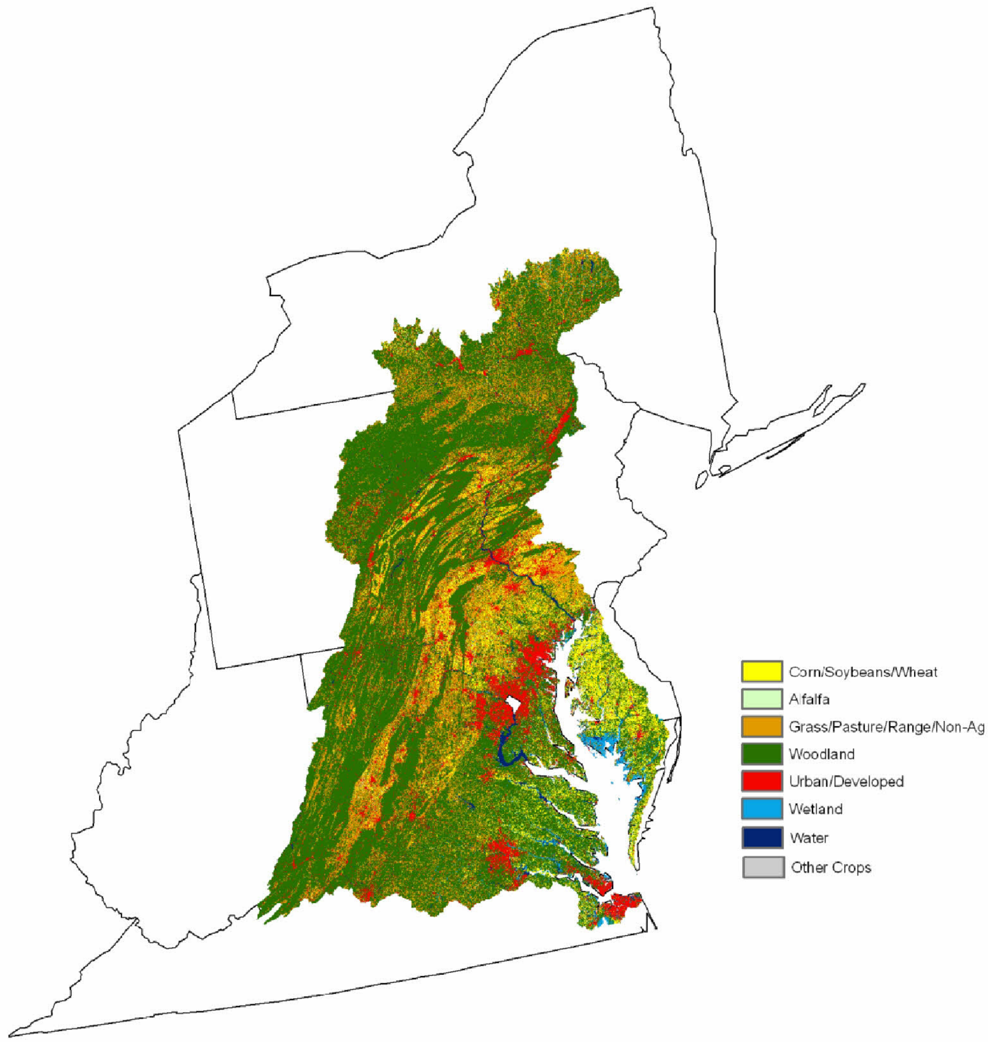
# Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Chesapeake Bay Watershed



**CEAP—Strengthening the science base for natural resource conservation**
The Conservation Effects Assessment Project (CEAP) was initiated by USDA's Natural Resources Conservation Service (NRCS), Agricultural Research Service (ARS), and Cooperative State Research, Education, and Extension Service (CSREES—now National Institute of Food and Agriculture [NIFA])) in response to a general call for better accountability of how society would benefit from the 2002 Farm Bill's substantial increase in conservation program funding (Mausbach and Dedrick 2004). The original goals of CEAP were to estimate conservation benefits for reporting at the national and regional levels and to establish the scientific understanding of the effects and benefits of conservation practices at the watershed scale. As CEAP evolved, the scope was expanded to provide research and assessment on how to best use conservation practices in managing agricultural landscapes to protect and enhance environmental quality.

CEAP activities are organized into three interconnected efforts:

- *Bibliographies, literature reviews, and scientific workshops* to establish what is known about the environmental effects of conservation practices at the field and watershed scale.

- *National and regional assessments* to estimate the environmental effects and benefits of conservation practices on the landscape and to estimate conservation treatment needs. The four components of the national and regional assessment effort are *Cropland*; *Wetlands*; *Grazing lands*, including rangeland, pastureland, and grazed forest land; and *Wildlife*.

- *Watershed studies* to provide in-depth quantification of water quality and soil quality impacts of conservation practices at the local level and to provide insight on what practices are the most effective and where they are needed within a watershed to achieve environmental goals.

Research and assessment efforts were designed to estimate the effects and benefits of conservation practices through a mix of research, data collection, model development, and model application. Duriancik et al. (2008) summarize the accomplishments of CEAP through 2007. A vision for how CEAP can contribute to better and more effective delivery of conservation programs in the years ahead is addressed in Maresch, Walbridge, and Kugler (2008). Additional information on the scope of the project can be found at http://www.nrcs.usda.gov/technical/nri/ceap/.

This report was prepared by the Conservation Effects Assessment Project (CEAP) Cropland Modeling Team and published by the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). The modeling team consists of scientists and analysts from NRCS, the Agricultural Research Service (ARS), Texas AgriLife Research, and the University of Massachusetts.

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## Acknowledgements

The modeling team thanks former NRCS Chiefs **Arlen Lancaster** and **Bruce Knight** for their support and guidance in the initiation and implementation of CEAP. The team also thanks the current NRCS Chief, **Dave White**, for his support in the completion and publication of the report.

## Foreword

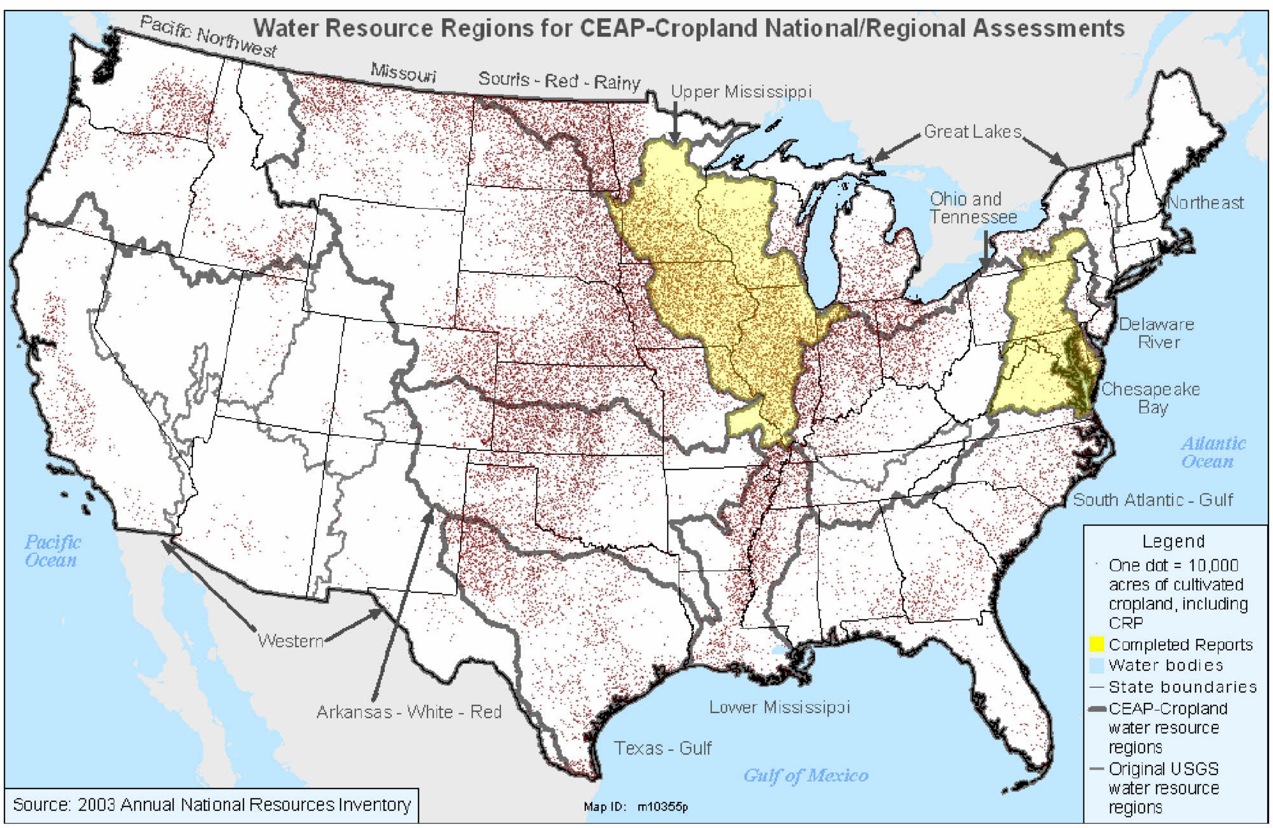
The United States Department of Agriculture has a rich tradition of working with farmers and ranchers to enhance agricultural productivity and environmental protection. Conservation pioneer Hugh Hammond Bennett worked tirelessly to establish a nationwide Soil Conservation Service along with a system of Soil and Water Conservation Districts. The purpose of these entities, now as then, is to work with farmers and ranchers and help them select and apply conservation practices to enable their operations to produce food, forage, and fiber while conserving the Nation's soil and water resources.

USDA conservation programs are voluntary. Many provide financial assistance to producers to help encourage adoption of conservation practices. Others provide technical assistance to design and install conservation practices suitable to the goals of the agricultural operation and the soil, climatic, and hydrologic setting. By participating in USDA conservation programs, producers are able to—

- install structural practices such as riparian buffers, grass filter strips, terraces, grassed waterways, and contour farming to reduce erosion, sedimentation, and nutrients leaving the field;
- adopt conservation systems and practices such as conservation tillage, comprehensive nutrient management, integrated pest management, and irrigation water management to maintain the long-term productivity of crop and pasture land; and
- retire land too fragile for continued agricultural production by planting and maintaining on them grasses, trees, or wetland vegetation.

Once soil conservation became a national priority, assessing the effectiveness of conservation practices has been important. Over the past several decades, the relationship between crop production and the landscape in which it occurs has become better understood in terms of the impact on sustainable agricultural productivity and the impact of agricultural production on other ecosystem services that the landscape has potential to generate. Accordingly, the objectives of USDA conservation policy have expanded along with the development of conservation practices to achieve them.

This report on the Chesapeake Bay region is the second in a series of regional reports that continues the tradition within USDA of assessing the status, condition, and trends of natural resources to determine how to improve conservation programs to best meet the Nation's needs. These reports use a sampling and modeling approach to quantify the environmental benefits that farmers and conservation programs are currently providing to society, and explore prospects for attaining additional benefits with further conservation treatment. Subsequent reports on cultivated cropland will be prepared for regions shown in the following map.



# Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Chesapeake Bay Region

## Contents

## Documentation Reports

There are a series of documentation reports and associated publications by the modeling team posted on the CEAP website at: http://www.nrcs.usda.gov/technical/nri/ceap/Cropland.html. Included are the following reports that provide details on the modeling and databases used in this study:

- The CEAP-HUMUS National Water Quality Modeling System and Databases
- Calibration and Validation of CEAP-HUMUS
- Delivery Ratios Used in CEAP Cropland Modeling
- APEX Model Validation for CEAP
- Documentation of Pesticide Risk Indicators Used in the CEAP Cropland Modeling
- NRI-CEAP Cropland Survey Design and Statistical Documentation
- Transforming Survey Data to APEX Model Input Files
- Modeling Structural Conservation Practices for the Cropland Component of the National Conservation Effects Assessment Project
- APEX Model Upgrades, Data Inputs, and Parameter Settings for Use in CEAP Cropland Modeling
- APEX Calibration and Validation Using Research Plots in Tifton, Georgia
- The Agricultural Policy Environmental EXtender (APEX) Model: An Emerging Tool for Landscape and Watershed Environmental Analyses
- The Soil and Water Assessment Tool: Historical Development, Applications, and Future Research Directions
- Historical Development and Applications of the EPIC and APEX Models
- Assumptions and Procedures for Simulating the Natural Vegetation Background Scenario for Cropland

# Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Chesapeake Bay region

## Executive Summary


Good progress has been made on reducing sediment, nutrient, and pesticide losses from farm fields through conservation practice implementation in the Chesapeake Bay region, but a significant amount of conservation treatment remains to be done to reduce nonpoint agricultural sources of pollution.

- Use of soil erosion control practices is widespread, with most acres receiving some form of erosion control treatment. Nevertheless, about 26 percent of the cultivated cropland acres still have excessive sediment loss from fields and require additional erosion control practices.
- Complete and consistent use of nutrient management (proper rate, form, timing, *and* method of application) is generally lacking throughout the region. About 81 percent of the cultivated cropland acres require additional nutrient management to reduce the loss of nitrogen or phosphorus from fields.
- The most critical conservation concern in the region is loss of nitrogen through subsurface loss pathways, most of which eventually contribute to surface water loads. About 65 percent of cropped acres require additional nutrient management to address excessive levels of nitrogen loss in subsurface flow pathways, including surface and subsurface drainage systems. About 28 percent of cropped acres need treatment *only* for nitrogen loss in subsurface flows.
- About half of the cropped acres are critically under-treated, usually requiring treatment for multiple natural resource problems. These are the most vulnerable and/or under-treated acres with the highest losses in the region.
- Model simulations of additional conservation treatment show that nutrient loss from fields is within acceptable levels when soil erosion control practices are paired with management of rate, form, timing, and method of nutrient application that maximizes the availability of nutrients for crop growth while minimizing environmental losses.
- Treatment of erosion alone can exacerbate the nitrogen loss problem because reducing surface water increases infiltration and, therefore, movement of soluble nitrogen into subsurface flow pathways. A *suite* of practices that includes both soil erosion control and consistent nutrient management is required to simultaneously address soil erosion *and* nutrient loss.
- Conservation practices in the region have also been effective in reducing pesticide residues lost from fields as well as the associated environmental risk.

Cultivated cropland represents only about 10 percent of the land base in the Chesapeake Bay watershed. With the current level of conservation treatment, cultivated cropland delivers a disproportionate amount of sediment and nutrients to rivers and streams and ultimately to the Bay. Of the total loads <u>delivered to rivers and streams</u> from all sources, cultivated cropland is the source for 25 percent of the sediment, 27.5 percent of the phosphorus, and 32 percent of the nitrogen.

Conservation practices in use on cultivated cropland within the watershed are responsible for reducing total loads <u>delivered to the Bay</u> (all sources) by 14 percent for sediment, 15 percent for phosphorus, and 15 percent for nitrogen.

If all the under-treated acres (81 percent of cropped acres) were fully treated with the appropriate soil erosion control and/or nutrient management practices, total loads <u>delivered to the Bay</u> (all sources) would be reduced from current levels by 7 percent for sediment (bringing loads from cultivated cropland down very close to "background levels,") 17 percent for phosphorus, and 16 percent for nitrogen.

This study was designed to quantify the effects of conservation practices commonly used on cultivated cropland in the Chesapeake Bay region, evaluate the need for additional conservation treatment in the region, and estimate the potential gains that could be attained with additional conservation treatment.

For purposes of this report, cultivated cropland includes land in row crops or close-grown crops (such as small grains), hay and pasture in rotation with row crops and close-grown crops, and cropland in long-term conserving cover. The Chesapeake Bay region has about 4.38 million acres of cultivated cropland—4.28 million cropped acres and about 0.1 million acres in long-term conserving cover. Acres enrolled in the General Signup of the Conservation Reserve Program (CRP) were used to represent land in long-term conserving cover.

A simulation model was used to estimate the effects of conservation practices that were in use during the period 2003 to 2006. The National Resources Inventory, a statistical survey of conditions and trends in soil, water, and related resources on U.S. non-Federal land conducted by USDA's Natural Resources Conservation Service, provides the statistical framework. Information on farming activities and conservation practices was obtained from a farmer survey and other sources. Using those data, conservation practice effects were evaluated in terms of—
- reductions in losses of sediment, nutrients, and pesticides from fields;
- enhancement of soil quality through increases in soil organic carbon in the field; and
- reductions in instream loads of sediment, nutrients, and pesticides in the region's rivers and streams.

The CEAP sample (771 sample points for cropped acres and 61 sample points for CRP General Signup) was designed to allow reporting of results for the four major subbasins (4-digit Hydrologic Unit Code) within the region. The sample size is too small, in most cases, for reliable and defensible reporting of results for areas below the subbasin level. (A much larger sample would be required to obtain a reliable result for areas smaller than the subbasin level.)

The physical process models used in this study are mathematical representations of the real world designed to simulate complex and varying environmental events and conditions. To estimate the effects of conservation practices, model simulation results were used to make *relative comparisons* between two model runs—one that includes conservation practices and one that excludes conservation practices. All other aspects of the input data and the model parameters are held constant in the two model runs.

The assessment includes conservation practices in use regardless of how or why they came to be in use. It is not restricted to only those practices associated with Federal conservation programs; the assessment also includes the conservation efforts of States, independent organizations, and individual landowners and farm operators.

## The Baseline Conservation Condition

The first Federal conservation efforts on cropland were focused primarily on water management and soil erosion control. Structural practices such as waterways, terraces, and diversions were installed along with supporting practices such as contour farming and stripcropping. Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. The conservation compliance provisions in the 1985 Farm Bill sharpened the focus to treatment of the most erodible acres—highly erodible land. This legislation created the CRP as a mechanism for establishing long-term conserving cover on the most erodible cropland through multi-year contracts with landowners. More recently, the focus has shifted from soil conservation and sustainability to a broader goal of reducing all pollution impacts associated with agricultural production. Prominent among new concerns are the environmental effects of nutrient and pesticide export from farm fields.

The application of conservation practices in the Chesapeake Bay region closely reflects this history of Federal conservation programs and technical assistance. An assessment of the extent of conservation practice use in the Chesapeake Bay region for the period 2003–06, representing the "baseline conservation condition," found the following:

- Structural practices for controlling water erosion are in use on 46 percent of Chesapeake Bay region cropped acres, including 63 percent of the highly erodible land.
- About 88 percent of the acres meet tillage intensity criteria for no-till (48 percent) or mulch till (40 percent). However, only 38 percent of cropped acres meet these tillage criteria *and* are gaining soil organic carbon. An additional 36 percent of cropped acres are considered to be "maintaining" soil organic carbon (average annual loss less than 100 pounds per acre).

- Producers use residue and tillage management practices, structural practices, or both, on nearly all (96 percent) cropped acres in the region.
- Appropriate rates of nitrogen application (including manure) are in use on about 32 percent of the acres receiving nitrogen for all crops in the rotation.
- Appropriate timing of nitrogen application (including manure) is in use on about 54 percent of the acres receiving nitrogen for all crops in the rotation.
- Good nitrogen management practices (rate, timing, *and* method) are in use on only about 12 percent of the acres receiving nitrogen for all crops during every year of production.
- Good phosphorus management practices (rate, timing, *and* method) are in use on 19 percent of the acres receiving phosphorus for all crops during every year of production.
- While most acres have evidence of some nitrogen or phosphorus management, the majority of the acres in the region lack consistent use of appropriate rates *and* timing *and* method of application, including nearly all of the acres receiving manure.
- Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of 100,000 acres in the region (2 percent of cultivated cropland acres), of which 67 percent is highly erodible land.

## Effects of Conservation Practices for the Baseline Conservation Condition

Model simulation results show that, for cropped acres in the region, *on average* conservation practices have—

- reduced surface water flow from farm fields by 17 percent, re-routing the water to subsurface flow pathways;
- reduced sediment loss from fields by 62 percent;
- reduced total nitrogen loss (volatilization, denitrification, surface runoff, and subsurface flow losses) from fields by 30 percent:
  - reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 42 percent,
  - reduced nitrogen loss in subsurface flows by 32 percent;
- reduced total phosphorus loss from fields by 43 percent;
- reduced pesticide loss from fields to surface water, resulting in a 34-percent reduction in edge-of-field pesticide risk for aquatic ecosystems and a 30-percent reduction in edge-of-field pesticide risk for humans (all pesticides combined); and
- decreased the percentage of acres that are losing soil organic carbon from 72 percent to 60 percent.

The relatively smaller reduction in nitrogen loss in subsurface flows results from a combination of incomplete nutrient management and the re-routing of surface water runoff to subsurface flows by water erosion control practices on some acres in the region. On 15 percent of the cropped acres, nitrogen loss in subsurface flows increased as a result of conservation practices. Structural erosion control practices, residue management practices, and reduced tillage slow the flow of surface water runoff and allow more of the water to infiltrate into the soil. This re-routing of surface water to subsurface flows not only re-directs the dissolved nitrogen into subsurface flows but also can extract additional nitrogen from the soil as the water passes through the soil profile. On about 12 percent of the acres, the re-routing of surface water runoff to subsurface flow pathways results in enough additional nitrogen being leached from the soil to more than offset the reductions in nitrogen lost with surface runoff and produce a net increase in total nitrogen loss. Model simulation of additional conservation treatment shows that pairing effective nutrient management practices (consistent use of proper rate, form, timing, *and* method of application) with water erosion control practices reduces nitrogen loss in subsurface flows to acceptable levels for most acres in the region.

For land in long-term conserving cover (100,000 acres), soil erosion and sediment loss have been almost completely eliminated. Compared to a cropped condition without conservation practices, total nitrogen loss has been reduced by 90 percent, total phosphorus loss has been reduced by 96 percent, and soil organic carbon has been increased by an average of more than 333 pounds per acre.

These reductions in field-level losses due to conservation practices, including land in long-term conserving cover, translate into improvements in water quality in streams and rivers in the region. Transport of sediment, nutrients, and pesticides from farm fields to streams and rivers involves a variety of processes and time-lags, and not all of the potential pollutants leaving fields contribute to instream loads. Loads from cultivated cropland <u>delivered to rivers and streams</u> in the watershed have been reduced by—

- 64 percent for sediment,
- 43 percent for phosphorus,

- 36 percent for nitrogen, and
- 31 percent for atrazine.

When considered along with loads from all other sources, conservation practices in use on cultivated cropland within the watershed are responsible for reducing total loads delivered to the Bay (all sources) by—
- 14 percent for sediment,
- 15 percent for phosphorus,
- 15 percent for nitrogen, and
- 26 percent for atrazine.

If the current level of conservation practice use is not maintained, some of these gains in water quality will be lost.

## Evaluation of Conservation Treatment Needs

This study also determined that the *combination* of practices in use was often inadequate to address excessive losses of sediment *and* nutrients. Adequate conservation treatment consists of combinations of conservation practices that treat the specific inherent vulnerability factors associated with each field for *both* sediment and nutrient loss. Not all acres require the same level of conservation treatment because of differences in climate and inherent soil vulnerabilities. The evaluation of conservation treatment needs was conducted by identifying acres that were inadequately treated with respect to the soil runoff or soil leaching potential.

The evaluation of treatment needs for the Chesapeake Bay region determined that—
- 3.5 million acres (81 percent of cropped acres) are under-treated for one or more of sediment loss, nitrogen or phosphorus lost with surface runoff, and nitrogen loss in subsurface flows:
    - Nearly all under-treated acres require additional treatment for either nitrogen or phosphorus loss,
    - 28 percent of cropped acres require additional treatment *only* for nitrogen loss in subsurface flows,
    - 16 percent of cropped acres require additional treatment for sediment loss, nitrogen and phosphorus runoff, *and* nitrogen leaching;
- Of the 3.5 million under-treated acres, 2.0 million acres (47 percent of cropped acres) are "critical" under-treated acres that consist of the most vulnerable acres in the region, most of which require treatment for multiple resource concerns; and
- 0.8 million acres (19 percent) are adequately treated relative to their degree of vulnerability.

Conservation treatment needs for further reducing the loss of pesticide residues were not estimated.

## Simulation of Additional Conservation Treatment

Additional conservation treatment was simulated for (1) the 2.0 million critical under-treated acres in the region, and (2) all 3.5 million under-treated acres. Two levels of treatment were simulated for each set of acres:
- *Treatment with additional erosion control practices*, which consisted of adding in-field practices to control overland flow (terraces, contouring, or stripcropping) for acres without overland flow control practices and having a slope of more than 2 percent, and adding edge-of-field buffering or filtering practices to all acres without edge-of-field practices.
- *Treatment with nutrient management in addition to erosion control practices*, which was modeled by adjusting the commercial fertilizer and manure applications to simulate the appropriate rate of application, the appropriate timing of application, and use of the appropriate application method.

Model simulation demonstrated that sediment and nutrient losses with surface runoff could be effectively controlled in the region by treating the 2.0 million most vulnerable under-treated acres with additional erosion control practices. At this level of treatment, model simulations showed the following for the region as a whole:
- Sediment loss from farm fields would average 0.4 ton per acre per year, compared to the baseline conservation condition average of 1.4 ton per acre per year (a 74-percent reduction).
- Nitrogen lost from the field with surface runoff (attached to sediment and in solution) would average 4.2 pounds per acre per year, compared to the baseline conservation condition average of 9.7 pounds per acre per year (a 57-percent reduction).
- Total phosphorus loss, most of which is lost to surface water, would average 2.4 pounds per acre per year, compared to 3.9 pounds per acre per year for the baseline conservation condition (a 39-percent reduction).

However, model simulations also showed that a portion of these nutrient savings was re-routed to subsurface loss pathways, most of which is eventually delivered to lakes, streams, and rivers through seepage, artificial drainage systems, and groundwater return flow. Treatment with nutrient management practices *in addition to* soil erosion control practices is required to effectively control the loss of soluble nitrogen and phosphorus from farm fields in the Chesapeake Bay region. Treatment at this level of all 3.5 million under-treated acres, compared to the baseline conservation condition, for the region as a whole would reduce nitrogen loss in subsurface flows from an average of 34.2 pounds per acre to an average of 23.0 pounds per acre (a 33-percent reduction). Total nitrogen loss (all loss pathways) would be reduced 35 percent. Total phosphorus loss would be reduced to about 1.7 pounds per acre per year, on average, representing a 55-percent reduction from the baseline conservation condition.

Model simulations further showed that the additional reductions in field-level losses would be expected to provide the following improvements in water quality within the region, compared to the baseline conservation condition.

**Percent reductions of instream loads delivered to the Chesapeake Bay due to additional erosion control and nutrient management**

| Environmental outcome | Treatment of the 2.0 million most vulnerable under-treated acres | Treatment of all 3.5 million under-treated acres |
|---|---|---|
| Sediment reduction | 5% | 7% |
| Nitrogen reduction | 12% | 16% |
| Phosphorus reduction | 13% | 17% |
| Atrazine reduction | 10% | 11% |

The nutrient management treatment level simulated in this study represents feasible and proven conservation practices that can be successfully applied using today's technology. There are, however, emerging conservation technologies that have the potential to further reduce nutrient loss from farm fields and provide even greater conservation benefits once the technologies become more widespread. These include—

- variable rate technology for precise nutrient application rates and placement methods;
- nitrogen use efficiency enhancers (time release and ammonia loss inhibitors);
- water control management which reduces late fall and early spring flushes of nitrate-laden drainage water; and
- constructed wetlands that receive surface water runoff from fields prior to discharge to streams and rivers.

Not all acres get the same benefit from conservation treatment. The more vulnerable acres, such as highly erodible land and soils prone to leaching, inherently lose more sediment and/or nutrients, and therefore greater benefit can be attained with conservation treatment. The gains in efficiency by treating the more vulnerable acres first are demonstrated in the table below using results from the treatment simulations:

**Average annual per-acre reductions in loss from treatment of designated acres with additional erosion control and nutrient management**

| Resource concern | 2.0 million critical under-treated acres | 1.5 million non-critical under-treated acres | Remaining 0.8 million acres |
|---|---|---|---|
| Sediment loss at edge of field due to water erosion (tons/acre) | 2.2 | 0.5 | 0.4 |
| Total nitrogen loss for all pathways (pounds/acre) | 40 | 28 | 3 |
| Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre) | 12 | 4 | 2 |
| Loss of nitrogen in subsurface flows (pounds/acre) | 24 | 20 | <1 |
| Total phosphorus loss for all pathways (pounds/acre) | 5.0 | 2.1 | 0.5 |

## Chesapeake Bay Region Has Greater Potential for Sediment and Nutrient Loss from Fields than Upper Mississippi River Basin

Vulnerability factors related to the loss of sediment and nutrients from cropped acres are greater in the Chesapeake Bay region (CB) than in the Upper Mississippi River Basin (UMRB), resulting in larger per-acre losses, on average, and a higher proportion of cropped acres that need additional conservation treatment. The Chesapeake Bay region has—

- Higher annual precipitation, averaging 8 more inches per year than in the UMRB.
- Higher percentage of cropped acres with slopes greater than 2 percent (60 percent compared to 42 percent for the UMRB)
- Higher percentage of cropped acres that are Highly Erodible Land (HEL) (44 percent compared to 18 percent for the UMRB).
- Higher percentage of cropped acres with a "high" soil runoff potential--soils prone to surface water runoff (23 percent compared to 13 percent for the UMRB).
- Higher percentage of cropped acres with a "high" or "moderately high" soil leaching potential—soils prone to leaching (46 percent compared to 9 percent for the UMRB).

Other important differences include—

- The CB has a lower percentage of cultivated cropland within the region (10 percent of the land area compared to 50 percent in the UMRB), which moderates the impact of cultivation on water quality in the region compared to the UMRB.
- The CB has twice the percentage of cropped acres with manure applied (38 percent for the CB compared to 18 percent for the UMRB).

The overall level of conservation practice use is about the same in both regions—

- The proportion of cropped acres with water erosion control structural practices is 46 percent in the CB, compared to 45 percent in the UMRB.
- Most of the cropped acres in both regions meet tillage criteria for either no-till or mulch till (88 percent of cropped acres in the CB compared to 91 percent in the UMRB). However, the UMRB has a higher percentage of cropped acres that are enhancing (gaining) soil organic carbon (75 percent for the UMRB compared to 40 percent for the CB).
- Use of nitrogen management practices (rate, timing, method of application) is the same—36 percent of cropped acres in each region have a "high" or "moderately high" level of nitrogen management.
- Use of phosphorus management practices (rate, timing, method of application) is proportionately higher in the UMRB than in the CB—39 percent of cropped acres in the CB have a "high" or "moderately high" level of phosphorus management compared to 57 percent in the UMRB.
- The Chesapeake Bay has a lower percentage of cropland in the Conservation Reserve Program General Signup (2 percent for the CB in 2003 compared to 5 percent for the UMRB).

Because of the higher vulnerability factors, the Chesapeake Bay region has higher average annual losses of sediment, nitrogen, and phosphorus from fields than the UMRB. For the baseline conservation condition—

- Sediment loss from fields averages 1.4 tons per acre in the CB compared to 1.0 tons per acre in the UMRB.
- Total nitrogen loss from fields averages 53 pounds per acre in the CB compared to 41 pounds per acre in the UMRB.
- Total phosphorus loss from fields averages 3.8 pounds per acre in the CB compared to 3.0 pounds per acre in the UMRB.

Consequently, 81 percent of the cropped acres in the Chesapeake Bay region need additional conservation treatment, compared to 62 percent in the UMRB. About half of the cropped acres in the Chesapeake Bay region are critically under-treated, compared to only 15 percent in the UMRB.

# Chapter 1
# Land Use and Agriculture in the Chesapeake Bay region

## Land use

The Chesapeake Bay region covers about 68,500 square miles and includes parts of New York, Pennsylvania, Maryland, Delaware, Virginia, and West Virginia. About 10 percent of the area is used for crop production (table 1 and figures 1 and 2), representing less than 1 percent of the Nation's cultivated cropland.

The majority of the land cover in the Chesapeake Bay region is forest land, which covers about 59 percent of the region. The forests consist primarily of deciduous trees with conifers and mixed stands in some areas. Pastureland and hay land make up about 18 percent of the land cover in the region. About 6 percent of the area is in water and wetlands.

Urban areas make up about 8 percent of the basin. The major metropolitan areas are Washington, DC; Baltimore, MD; Richmond, VA; Norfolk VA; and Harrisburg, PA.

## Agriculture

The 2007 Census of Agriculture reported 83,775 farms in the Chesapeake Bay region, about 4 percent of the total number of farms in the United States (table 2). Farms in the Chesapeake Bay region make up about 1 percent of all farmland in the nation. According to the 2007 Census of Agriculture, the value of Chesapeake Bay region agricultural sales in 2002 was about $9.3 billion—24 percent from crops and 76 percent from livestock.

About 51 percent of Chesapeake Bay region farms primarily raise crops, about 42 percent are primarily livestock operations, and the remaining 7 percent produce a mix of livestock and crops (table 3).

Most of the farms (74 percent) in 2007 were small operations with less than $50,000 in total farm sales. About 7 percent of the farms had total farm sales greater than $500,000 (table 3).

Forty-three percent of the farms in the Chesapeake Bay region are smaller than 50 acres, and 51 percent are between 50 and 500 acres. Only 6 percent of the farms have more than 500 acres (table 3).

### Crop production

The Chesapeake Bay region accounts for about 2 percent of all U.S. crop sales (table 2). Corn, soybeans and hay are the principal crops grown. Wheat is an important secondary crop in terms of acres harvested.

Farmers in the region produced 2 percent of the corn harvested for grain in the United States in 2007—163 million bushels—on about 1.5 million acres. Hay, grass silage, haylage, and greenchop were harvested on 2.2 million acres. Farms in the region also produced 2 percent of the national soybean crop (31.9 million bushels) on 1.1 million acres.

Commercial fertilizers and pesticides are widely used on cultivated cropland throughout the region (table 2). In 2007, 4.1 million acres of cropland were fertilized, 3.3 million acres of cropland and pasture were treated with chemicals for weed control, and 1.7 million acres of cropland were treated for insect control. About 1.7 million acres had manure applied in 2007.

Irrigation is used on some acres to supplement rainfall during dry periods. About 4 percent of the harvested acres were irrigated in 2007.

### Livestock operations

Livestock production in the region is dominated by poultry production, followed by dairy. Livestock operations in the region produced 10 percent of all poultry and egg sales in the United States in 2007, exceeding $3.7 billion in value (table 2). Sales of dairy products ranked second in the region at $ 2.2 billion, representing 7 percent of the U.S. total. Populations of pastured cattle, horses, and ponies are also significant, representing about one-third of the total livestock population in the region in 2007 (table 2).

Although 66 percent of the farms in the Chesapeake Bay region (55,600 farms) reported livestock sales in 2007, the majority are small operations. About 29,000 of these farms had fewer than 30 animal units[2] on the farm; a small number of these had specialty livestock such as rabbits, bison, mink, or deer (table 3). Pastured livestock (cattle, horses, sheep, or goats) predominate on about 14,000 farms; 81 percent of these farms raised fewer than 100 animal units in 2007. About 13,700 farms could be defined as animal feeding operations (AFOs). AFOs are typically livestock operations with confined livestock, such as poultry, swine, cattle on feed, or dairies. Sixteen percent of the farms in the Chesapeake Bay region are AFOs, although the bulk of these are relatively small operations. Only about 600 of the livestock operations (4 percent of the AFOs) are large, with livestock numbers in 2007 above the threshold for a Concentrated Animal Feeding Operation (CAFO).

## Watersheds

A hydrologic accounting system consisting of water resource regions, major subbasins, and smaller watersheds has been defined by the U.S. Geological Survey (USGS) (1980). In this study, the Chesapeake Bay region is represented by four subbasins within the Mid-Atlantic Water Resource Region. Each water resource region is designated with a 2-digit code, which is further divided into 4-digit subbasins and then into 8-digit watersheds, or Hydrologic Unit Codes (HUCs).

[2] An animal unit is 1,000 pounds of live animal weight.

The 4 subasins within the Chesapeake Bay region are shown in figure 3, and agricultural land use within each subbasin is summarized in table 4. The highest concentration of cultivated cropland, 24 percent) is in subbasin 0206—the Upper Chesapeake Bay subbasin. The Susquehanna River subbasin has about 11 percent of the land base in cultivated cropland, and the remaining two subbasins have 5-6 percent of the land base in cultivated cropland. About three-fourths of the cultivated cropland in the region is in either the Susquehanna River subbasin or the Upper Chesapeake Bay subbasin.

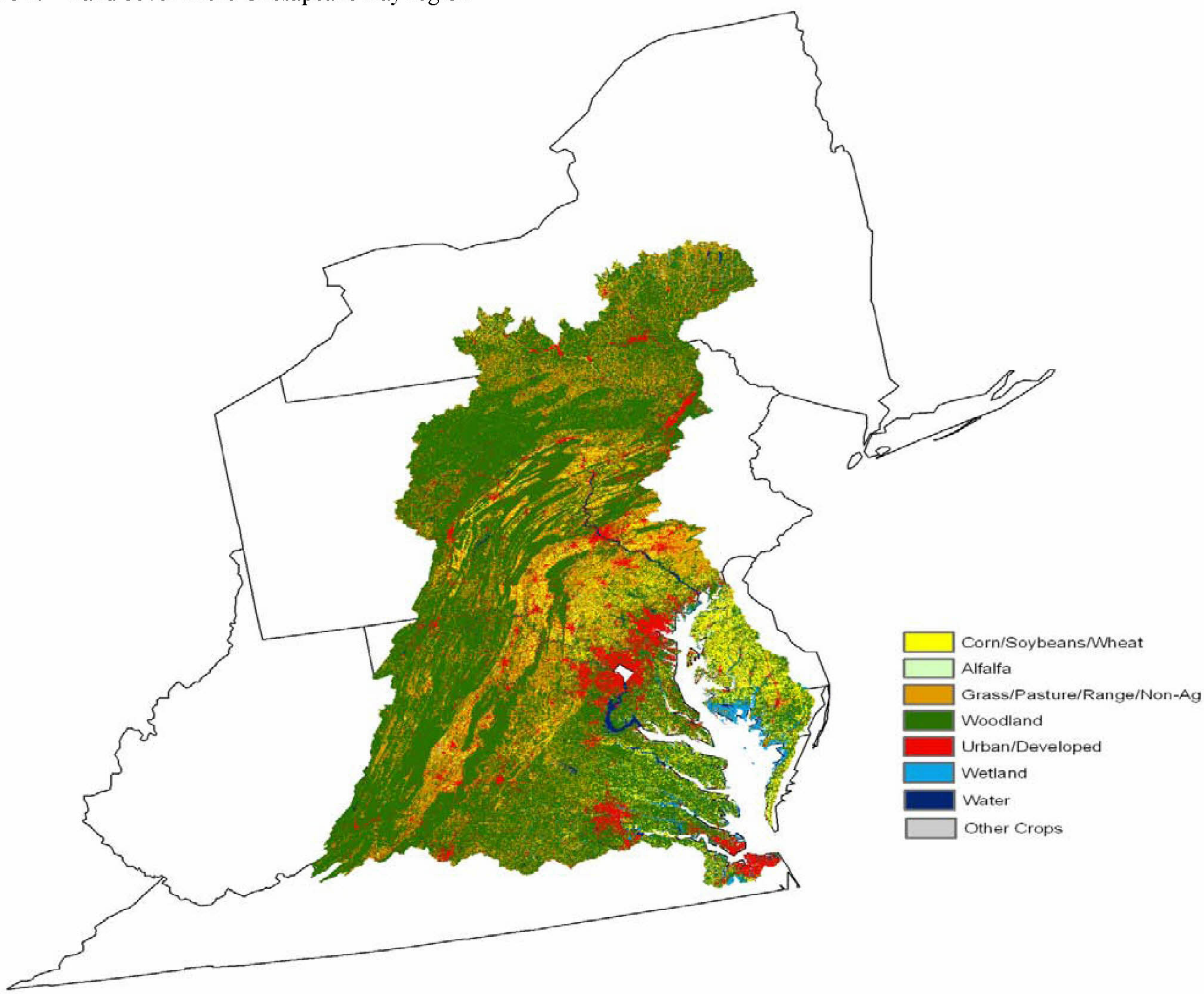
Estimates presented in this report for off-site water quality (instream loadings) exclude two 8-digit watersheds in the Upper Chesapeake Bay subbasin that drain to the Atlantic Ocean (8-digit HUCs 02060010 and 02080110). However, all other tables and figures in the report, including estimates of edge-of-field losses in Chapters 4 and 7 and conservation treatment needs in Chapter 6, *include* the cropped acres in these two 8-digit HUCs.

**Table 1.** Distribution of land cover in the Chesapeake Bay region

| Land use | Acres* | Percent |
|---|---|---|
| Cultivated cropland and land enrolled in the CRP General Signup | 4,588,332 | 10 |
| Forest deciduous | 19,106,747 | 44 |
| Hay/Pasture not in rotation with crops | 7,738,805 | 18 |
| Urban | 3,651,000 | 8 |
| Water | 1,152,262 | 3 |
| Wetland forested | 793,516 | 2 |
| Range grasses | 142,690 | <1 |
| Wetland non-forested | 517,632 | 1 |
| Forest evergreen | 2,999,538 | 7 |
| Forest mixed | 2,421,677 | 6 |
| Range brush | 266,807 | 1 |
| Horticulture and barren | 473,994 | 1 |
| **Total** | 43,853,000 | 100 |

Source: National Agricultural Statistics Service (NASS), 2007.
*Acreage estimates for cultivated cropland differ slightly from those provided elsewhere in this report because of differences in sources and methods.

**Figure 1.** Land cover in the Chesapeake Bay region




Source: National Agricultural Statistics Service (NASS), 2007.

**Figure 2.** Percent acres for land use/cover types in the Chesapeake Bay region

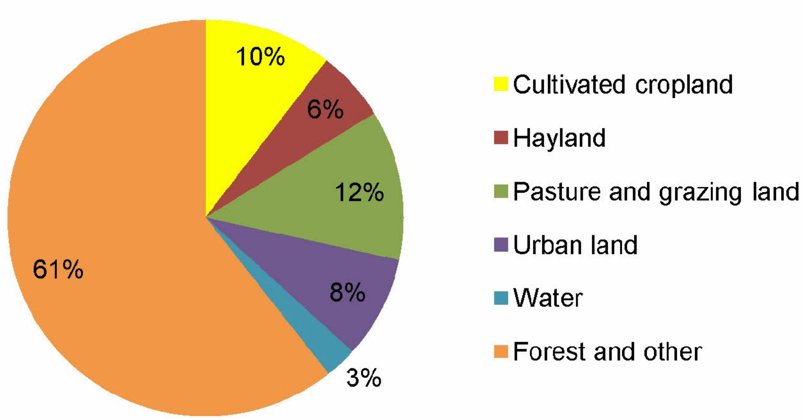


**Table 2**. Profile of farms in the Chesapeake Bay region, 2007

| Characteristic | Value | Percent of national total |
|---|---|---|
| Number of farms | 83,775 | 4 |
| Acres on farms | 12,826,065 | 1 |
| Average acres per farm | 153 | |
| | | |
| Cropland harvested, acres | 6,027,682 | 2 |
| Cropland used for pasture, acres | 606,584 | 2 |
| Cropland on which all crops failed, acres | 73,359 | 1 |
| Cropland in summer fallow, acres | 39,109 | <1 |
| Cropland idle or used for cover crops, acres | 447,020 | 1 |
| Woodland pastured, acres | 383,612 | 1 |
| Woodland not pastured, acres | 2,609,960 | 6 |
| Permanent pasture and rangeland, acres | 1,925,684 | <1 |
| Other land on farms, acres | 713,055 | 2 |
| | | |
| Principal crops grown | | |
| Field corn for grain harvested, acres | 1,546,362 | 2 |
| Field corn for silage harvested, acres | 551,955 | 9 |
| Soybeans harvested, acres | 1,066,151 | 2 |
| Wheat harvested, sum acres | 455,516 | 1 |
| Alfalfa hay harvested, acres | 436,156 | 2 |
| Grass silage, haylage, and greenchop harvested, acres | 308,028 | 9 |
| Tame and wild hay harvested, acres | 1,506,020 | 4 |
| | | |
| Irrigated harvested land, acres | 240,438 | <1 |
| Irrigated pastureland or rangeland, acres | 3,707 | <1 |
| Cropland fertilized, acres | 4,103,629 | 2 |
| Pastureland fertilized, acres | 410,840 | 2 |
| Land treated for insects on hay or other crops, acres | 1,701,146 | 2 |
| Land treated for nematodes in crops, acres | 111,728 | 1 |
| Land treated for diseases in crops and orchards, acres | 267,317 | 1 |
| Land treated for weeds in crops and pasture, acres | 3,320,537 | 1 |
| Crops on which chemicals for defoliation applied, acres | 77,940 | 1 |
| Acres on which manure was applied | 1,716,448 | 8 |
| | | |
| Total grains and oilseeds sales, million dollars | 915,631,290 | 1 |
| Total fruit and berry sales, million dollars | 197,357,734 | 1 |
| Total vegetable, melons sales, million dollars | 279,696,733 | 2 |
| Total nursery, greenhouse, and floriculture sales, million dollars | 611,617,415 | 4 |
| Total hay other crop sales, million dollars | 239,943,957 | 1 |
| Total crop sales, million dollars | 2,004,303,172 | 2 |
| | | |
| Total dairy sales, million dollars | 2,150,033,444 | 7 |
| Total hog and pigs sales, million dollars | 343,587,556 | 2 |
| Total poultry and eggs sales, million dollars | 3,711,452,954 | 10 |
| Total cattle sales, million dollars | 843,470,000 | 1 |
| Total sheep, goats, and their products sales, million dollars | 15,958,047 | 2 |
| Total horses, ponies, and mules sales, million dollars | 107,465,458 | 5 |
| Total other livestock sales, million dollars | 99,358,748 | 4 |
| Total livestock sales, million dollars | 7,271,326,207 | 5 |
| | | |
| Animal units on farms | | |
| All livestock types | 3,221,469 | 3 |
| Swine | 187,118 | 2 |
| Dairy cows | 853,938 | 7 |
| Fattened cattle | 107,140 | 1 |
| Other cattle, horses, sheep, goats | 1,229,906 | 2 |
| Chickens, turkeys, and ducks | 831,182 | 10 |
| Other livestock | 12,185 | 3 |

Source: 2007 Census of Agriculture, National Agricultural Statistics Service, USDA

Note: Information in the Census of Agriculture was used to estimate animal units using methods and assumptions described in USDA-NRCS (2003).

**Table 3**. Characteristics of farms in the Chesapeake Bay region, 2007

| | Number of farms | Percent of farms in Chesapeake Bay region |
|---|---|---|
| Farming primary occupation | 39,584 | 47 |
| Farm size: | | |
| <50 acres | 36,142 | 43 |
| 50–500 acres | 42,795 | 51 |
| 500–2,000 acres | 4,399 | 5 |
| >2,000 acres | 439 | 1 |
| Farm sales: | | |
| <$10,000 | 45,013 | 54 |
| $10,000–50,000 | 16,754 | 20 |
| $50,000–250,000 | 11,217 | 13 |
| $250,000–500,000 | 4,657 | 6 |
| >$500,000 | 6,134 | 7 |
| Farm type: | | |
| Crop sales make up more than 75% of farm sales | 42,630 | 51 |
| Livestock sales make up more than 75% of farm sales | 35,334 | 42 |
| Mixed crop and livestock sales | 5,811 | 7 |
| Farms with no livestock sales | 28,187 | 34 |
| Farms with few livestock or specialty livestock types | 27,751 | 33 |
| Farms with pastured livestock and few other livestock types | 14,143 | 17 |
| Farms with animal feeding operations (AFOs)* | 13,694 | 16 |

Source: 2007 Census of Agriculture, National Agricultural Statistics Service, USDA

* AFOs, as defined here, typically have a total of more than 12 animal units consisting of fattened cattle, dairy cows, hogs and pigs, chickens, ducks, and turkeys.

**Figure 3.** Percent cultivated cropland, including land in long-term conserving cover, for the 4 subbasins in the Chesapeake Bay region

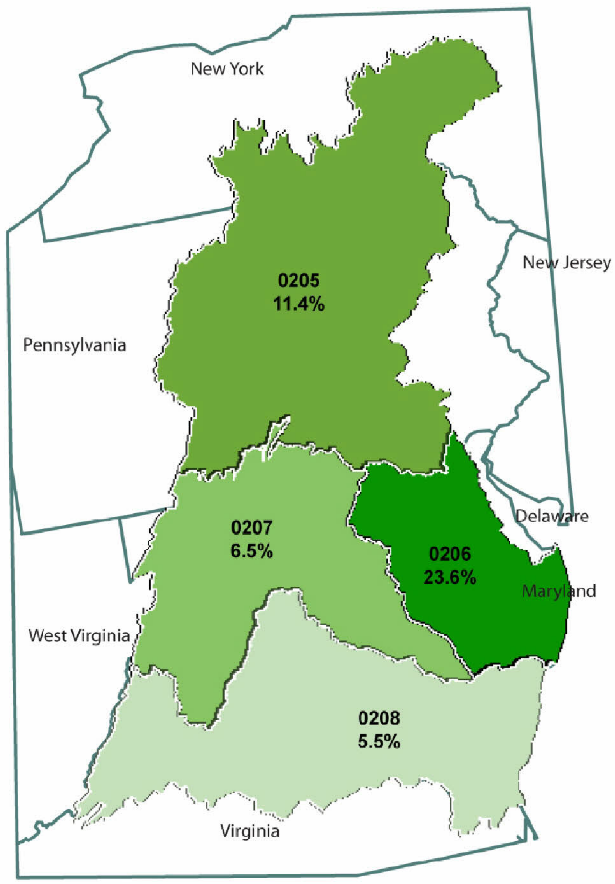



**Table 4**. Agricultural land use in the 4 subbasins in the Chesapeake Bay region

| Sub-basin code | Subbasin name | Total land (1,000 acres) | Cultivated cropland (1,000 acres)* | Percent cultivated cropland in subbasin | Percent of cultivated cropland in Chesapeake Bay region | Percent of cultivated cropland acres in long-term conserving cover | Hayland not in rotation with crops (1,000 acres) | Pastureland not in rotation with crops (1,000 acres) |
|---|---|---|---|---|---|---|---|---|
| 0205 | Susquehanna River | 17,596 | 2,008 | 11.4 | 43.8 | 4.0 | 1,315 | 1,438 |
| 0206 | Upper Chesapeake Bay | 5,773 | 1,361 | 23.6 | 29.7 | 1.1 | 54 | 879 |
| 0207 | Potomac River | 9,404 | 612 | 6.5 | 13.3 | 2.0 | 670 | 1,566 |
| 0208 | Lower Chesapeake Bay | 11,080 | 608 | 5.5 | 13.2 | 4.2 | 461 | 1,356 |
| | Total | 43,853 | 4,588 | 10.5 | 100 | 2.9 | 2,500 | 5,239 |

* Acres of cultivated cropland include land in long-term conserving cover.
Note: Estimates in this table were obtained from HUMUS databases on land use, and do not exactly match the acreage estimates obtained from the NRI-CEAP sample.

# Chapter 2
# Modeling the Effects of Conservation Practices

## Scope of Study

This report provides estimates for the Chesapeake Bay region of—

- environmental benefits and effects of conservation practices in use in the region;
- conservation treatment needs for the region; and
- potential gains that could be attained with additional conservation treatment.

The study was designed to quantify at the regional level the effects of commonly used conservation practices on cultivated cropland, regardless of how or why the practices came to be in use. This assessment is not an evaluation of Federal conservation programs, because it is not restricted to only those practices associated with Federal conservation programs.

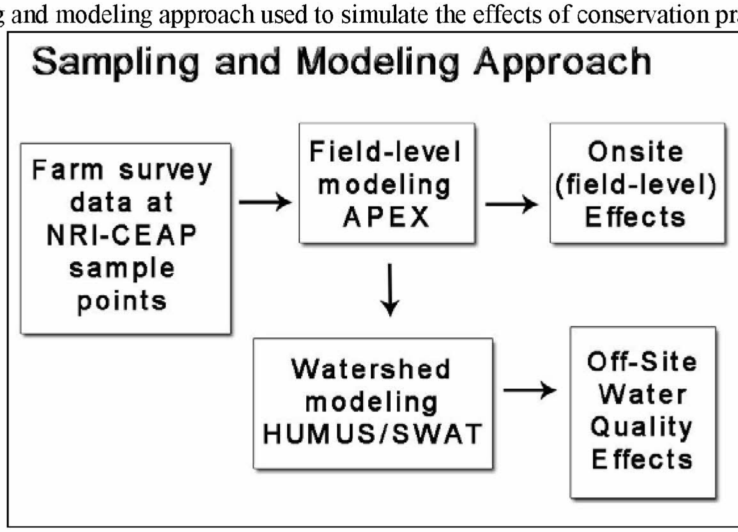
For purposes of this report, cultivated cropland includes land in row crops or close-grown crops, hay and pasture in rotation with row crops and close-grown crops, and land in long-term conserving cover. Cultivated cropland does not include agricultural land that has been in hay, pasture, or horticulture for 4 or more consecutive years. Acres enrolled in the General Signup of the Conservation Reserve Program (CRP) were used to represent cultivated cropland currently in long-term conserving cover. The Chesapeake Bay region has about 4.4 million acres of cultivated cropland—4.3 million cropped acres and about 0.1 million acres in long-term conserving cover.

## Overview of Sampling and Modeling Approach

The assessment uses a statistical sampling and modeling approach to estimate the environmental effects and benefits of conservation practices (figure 4).

- A subset of 771 National Resources Inventory (NRI) sample points provides a statistical sample that represents the diversity of soils and other conditions for cropped acres in the Chesapeake Bay region. The sample also includes 61 additional NRI sample points designated as CRP acres to represent land in long-term conserving cover. NRI sample points are linked to NRCS Soil Survey databases and were linked spatially to climate databases for this study.
- A farmer survey—the NRI-CEAP Cropland Survey—was conducted at these sample points during the period 2003–06 to determine what conservation practices were in use and to collect information on farming practices.
- The field-level effects of the conservation practices were assessed using a field-scale physical process model—the Agricultural Policy Environmental Extender (APEX)—which simulates the day-to-day farming activities, wind and water erosion, loss or gain of soil organic carbon, and edge-of-field losses of soil, nutrients, and pesticides.
- A watershed model and system of databases—the Hydrologic Unit Model for the United States (HUMUS)—was then used to simulate how reductions of field losses have reduced instream concentrations and loadings of sediment, nutrients, and pesticides within the Chesapeake Bay region. The SWAT model (Soil and Water Assessment Tool) was used to simulate nonpoint source loadings from land uses other than cropland and to route instream loads from one watershed to another.

**Figure 4.** Statistical sampling and modeling approach used to simulate the effects of conservation practices



The modeling strategy for estimating the effects of conservation practices consists of two model scenarios that are produced for each sample point.

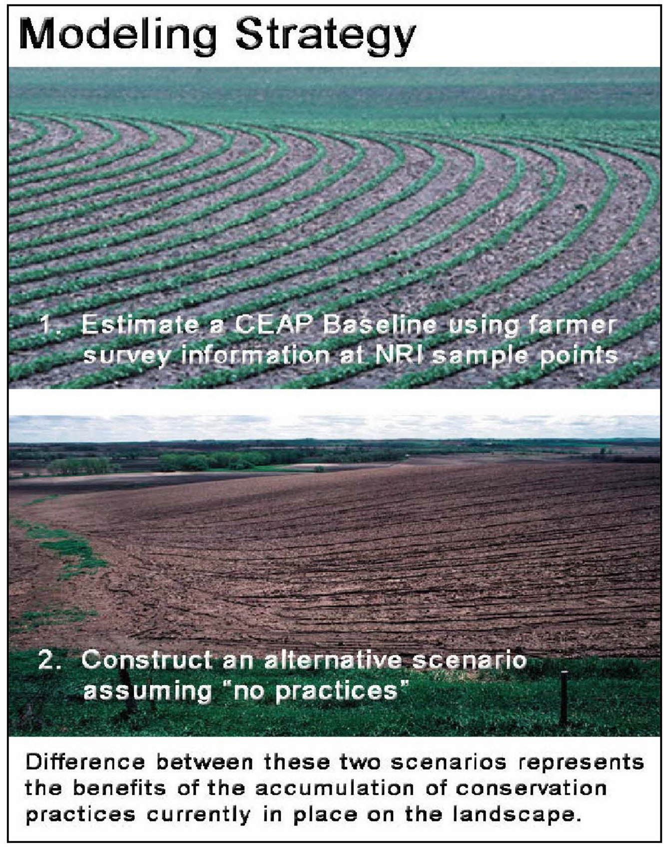
1. A baseline scenario, the "baseline conservation condition" scenario, provides model simulations that account for cropping patterns, farming activities, and conservation practices as reported in the NRI-CEAP Cropland Survey and other sources.
2. An alternative scenario, the "no-practice" scenario, simulates model results as if no conservation practices were in use but holds all other model inputs and parameters the same as in the current conservation condition scenario.

The effects of conservation practices are obtained by taking the difference in model results between the two scenarios (figure 5).[3] For example, to simulate "no practices" for sample points where some type of residue management is used, model simulations were conducted as if continuous conventional tillage had been used. Similarly, for sample points with structural conservation practices (buffers, terraces, grassed waterways, etc.), the no-practice scenario was simulated as if the practices were not present. The no-practice representation for land in long-term conserving cover was derived from model results for cropped acres as simulated in the no-practice scenario, representing how the land would have been managed had crops been grown without the use of conservation practices.

The approach captures the diversity of land use, soils, climate, and topography from the NRI; accounts for site-specific farming activities; estimates the loss of materials at the field scale where the science is most developed; and provides a statistical basis for aggregating results to the national and regional levels.

[3] This modeling strategy is similar to how the NRI produces estimates of soil erosion and the intrinsic erosion rate used to identify highly erodible land. The NRI uses the Universal Soil Loss Equation (USLE) to estimate sheet and rill erosion at each sample point on the basis of site-specific factors. Soil loss per unit area is equal to R*K*L*S*C*P. The first four factors—R, K, L, S—represent the conditions of climate, soil, and topography existing at a site. (USDA-NRCS 1989). The last two factors—C and P—represent the degree to which management influences the erosion rate. The product of the first four factors is sometimes called the intrinsic, or potential, erosion rate. The intrinsic erosion rate divided by T, the soil loss tolerance factor, produces estimates of EI, the erodibility index. The intrinsic erosion rate is thus a "no-practice" representation of sheet and rill erosion, since C=1 represents smooth-tilled continuous fallow and P=1 represents no supporting practices.

**Figure 5.** Modeling strategy used to assess effects of conservation practices




### The NRI and the CEAP subsample

The approach is an extension of the NRI, a longitudinal, scientifically-based survey designed to gauge natural resource status, conditions, and trends on the Nation's non-Federal land (Goebel 1998; USDA-NRCS 2002). NRCS has previously used the NRI for modeling to address issues related to natural resources and agriculture (Goebel and Kellogg 2002).[4]

The NRI sampling design implemented in 1982 provided a stratified, two-stage, unequal probability area sample of the entire country (Goebel and Baker 1987; Nusser and Goebel 1997). Nominally square areas/segments were selected within geographical strata on a county-by-county basis; specific point locations were selected within each selected segment. The segments ranged in size from 40 to 640 acres but were typically half-mile square areas, and most segments contained three sample points. At each sample point, information is collected on nearly 200 attributes; some items are also collected for the entire segment. The sampling rates for the segments were variable, typically from 2 to 6 percent in

[4] Previous studies have used this NRI micro-simulation modeling approach to estimate soil loss, nutrient loss, and change in soil organic carbon (Potter et al. 2006), to estimate pesticide loss from cropland (Kellogg et al. 1992, 1994, 2002; Goss et al. 1998), and to identify priority watersheds for water quality protection from nonpoint sources related to agriculture (Kellogg 2000, Kellogg et al. 1997).

agricultural strata and much lower in remote nonagricultural areas. The 1997 NRI Foundation Sample contained about 300,000 sample segments and about 800,000 sample points.

NRCS made several significant changes to the NRI program over the past 10 years, including transitioning from a 5-year periodic survey to an annual survey. The NRI's annual design is a *supplemented panel design.* A *core panel* of 41,000 segments is sampled each year, and *rotation (supplemental) panels* of 31,000 segments each vary by inventory year and allow an inventory to focus on an emerging issue. The core panel and the various supplemental panels are unequal probability subsamples from the 1997 NRI Foundation Sample.[5]

The CEAP cultivated cropland sample is a subset of NRI sample points from the 2003 NRI (USDA/NRCS, 2007). The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample.[6] The sample is statistically representative of cultivated cropland and formerly cultivated land currently in long-term conserving cover. Nationally, the NRI-CEAP sample consists of about 18,700 NRI points representing cropped acres,[7] and about 13,000 NRI points representing land enrolled in the General Signup of the CRP.

The Chesapeake Bay region portion of the NRI-CEAP sample consists of 771 sample points representing 4.3 million cropped acres and 61 sample points representing 0.1 million acres of agricultural land in long-term conserving cover. Table 5 provides a breakdown of sample sizes for the dominant cropping systems that occur in the Chesapeake Bay region. About 76 percent of the cultivated cropland acres include corn or soybean or both in the crop rotation.

The CEAP sample was designed to allow reporting of results for the four subbasins (4-digit HUCs) within the region. The acreage weights were derived so as to approximate total cropped acres by 4-digit HUC as estimated by the full 2003 NRI. The sample size is too small, in most cases, for reliable and defensible reporting of results for areas below the subbasin level.

Acres reported using the CEAP sample are "estimated" acres because of the uncertainty associated with the statistical sample. Standard errors for estimated acres used in this report are provided in Appendix A.

[5] For more information on the NRI, see www.nrcs.usda.gov/technical/NRI/.

[6] Information about the CEAP sample design is in "NRI-CEAP Cropland Survey Design and Statistical Documentation," available at http://www.nrcs.usda.gov/technical/nri/ceap/Cropland.html.

[7] A completed farmer survey was required to include the sample point in the CEAP sample. Some farmers declined to participate in the survey, others could not be located during the time period scheduled for implementing the survey, and other sample points were excluded for administrative reasons such as overlap with other USDA surveys. Some sample points were excluded because the surveys were incomplete or contained inconsistent information, land use found at the sample point had recently changed and was no longer cultivated cropland, or because the crops grown were uncommon and model parameters for crop growth were not available.

### The NRI-CEAP Cropland Survey

A farmer survey—the NRI-CEAP Cropland Survey—was conducted to obtain the additional information needed for modeling the 771 sample points with crops. The USDA National Agricultural Statistics Service (NASS) administered the survey. Farmer participation was voluntary, and the information gathered is confidential. The survey content was specifically designed to provide information on farming activities for use with a physical process model to estimate field-level effects of conservation practices. The survey obtained information on—[8]

- crops grown for the previous 3 years, including double crops and cover crops;
- field characteristics, such as proximity to a water body or wetland and presence of tile or surface drainage systems;
- conservation practices associated with the field;
- crop rotation plan;
- application of commercial fertilizers (rate, timing, method, and form) for crops grown the previous 3 years;
- application of manure (source and type, consistency, application rate, method, and timing) on the field over the previous 3 years;
- application of pesticides (chemical, rate, timing, and method) for the previous 3 years;
- pest management practices;
- irrigation practices (system type, amount, and frequency);
- timing and equipment used for all field operations (tillage, planting, cultivation, harvesting) over the previous 3 years;
- practices to improve wildlife habitat and operator's judgment on their effects on local wildlife populations; and
- general characteristics of the operator and the operation.

Farmers were also asked about the presence of structural conservation practices associated with the field. In a separate survey, NRCS field offices provided information on the practices specified in conservation plans.

Because of the large size of the sample, it was necessary to spread the data collection process over a 4-year period, from 2003 through 2006. In each year, surveys were obtained for a separate set of sample points. The final CEAP sample was constructed by pooling the set of usable, completed surveys from all four years.

Farmer responses to the NRI-CEAP Cropland Survey for the Chesapeake Bay region are summarized in Appendix B.

[8] The surveys, the enumerator instructions, and other documentation can be found at www.nrcs.usda.gov/technical/nri/ceap/surveys.html.

**Table 5.** Cultivated cropland in the Chesapeake Bay region

| Cropping System | Number of CEAP samples | Estimated acres | Percent of acres |
|---|---|---|---|
| Corn-soybean only | 246 | 1,174,736 | 27 |
| Corn-soybean with close grown crops | 180 | 830,308 | 19 |
| Corn only | 103 | 690,403 | 16 |
| Soybean only | 40 | 161,087 | 4 |
| Soybean-wheat only | 22 | 124,649 | 3 |
| Corn and close grown crops | 46 | 295,685 | 7 |
| Vegetable or tobacco with or without other crops | 24 | 139,064 | 3 |
| Hay-crop mix | 85 | 688,255 | 16 |
| Remaining mix of crops | 25 | 175,713 | 4 |
| Sub-total for cropped acres | 771 | 4,279,900 | 98 |
| CRP General Signup, representing cultivated cropland in long-term conserving cover | 61 | 100,300 | 2 |
| Total | 832 | 4,380,200 | 100 |

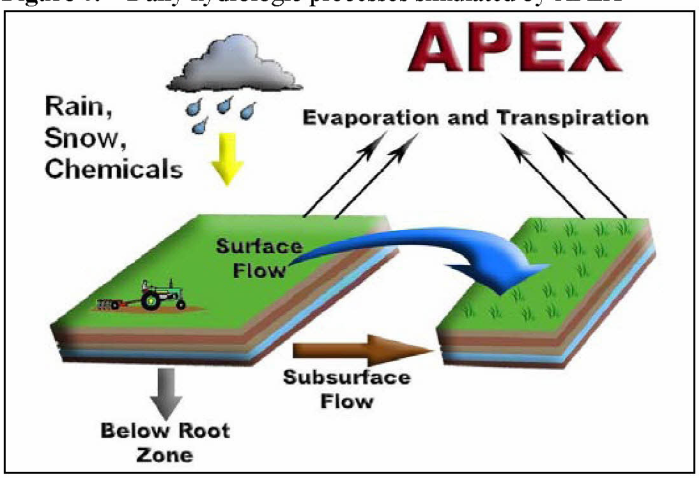
Note: Estimates are from the 2003 NRI and the NRI-CEAP Cropland Survey. Cultivated cropland acres in this table differ slightly from estimates presented in table 1 because of differences in sources and methods.

### The field-level cropland model—APEX

A physical process model called APEX was used to simulate the effects of conservation practices at the field level (Williams et al., 2008; Williams et al., 2006; Gassman et al. 2009 and 2010).[9] The I_APEX model run management software developed at the Center for Agricultural and Rural Development, Iowa State University, was used to perform the simulations in batch mode.[10]

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides (figure 6). The APEX model and its predecessor, EPIC (Environmental Policy Impact Calculator), have a long history of use in simulation of agricultural and environmental processes and of the effect of agricultural technology and government policy (Izaurralde et al., 2006;Williams, 1990; Williams et al., 1984;Gassman et al. 2005).[11]

**Figure 6.** Daily hydrologic processes simulated by APEX




On a daily basis, APEX simulates the farming operations used to grow crops, such as planting, tillage before and after planting, application of nutrients and pesticides, application of manure, irrigation, and harvest. Weather events and their interaction with crop cover and soil properties are simulated; these events affect crop growth and the fate and transport of water and chemicals through the soil profile and over land to the edge of the field. Over time, the chemical makeup and physical structure of the soil may change, which in turn affect crop yields and environmental outcomes. Crop residue remaining on the field after harvest is transformed into organic matter. Organic matter may build up in the soil over time, or it may degrade.

APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion, and the loss of sediment beyond the edge of the field. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field. Exchange of gaseous forms between the soil and the atmosphere is simulated, including losses of gaseous nitrogen compounds.

The NRI-CEAP Cropland Survey was the primary source of information on all farming activities simulated using APEX. Crop data were transformed for the model into a crop rotation for each sample point, which was then repeated over the 47-year simulation. The 3 years of data reported in the survey were represented in the model simulation as 1-, 2-, 3-, 4-, or 5-year crop rotations. For example, a 2-year corn-soybean rotation was used if the operator reported that corn was grown in the first year, soybeans in the second year, and corn again in the third year. In this case, only 2 of the reported 3 years of survey data were used. If management differed significantly for the 2 years that corn was grown (manure was applied, for example, or tillage was different), the rotation was expanded to 4 years, retaining the second year of corn and repeating the year of soybeans. In addition, some rotations with alfalfa or grass seed were simulated as 5-year rotations. Specific rules and procedures were established for using survey data to simulate cover crops, double crops, complex systems such as intercropping and nurse crops, perennial hay in rotations, abandoned crops, re-planting, multiple harvests, manure applications, irrigation, and grazing of cropland before and after harvest.[12]

Use of conservation practices in the Chesapeake Bay region was obtained from four sources: (1) NRI-CEAP Cropland Survey, (2) NRCS field offices, (3) USDA Farm Service Agency (FSA), and (4) the 2003 NRI. For each sample point, data from these four sources were pooled and duplicate practices discarded.[13]

### The national water quality model—HUMUS/SWAT

Offsite estimates of water quality benefits were assessed using HUMUS/SWAT, a combination of the SWAT model and HUMUS (Hydrologic Unit Modeling for the United States) databases required to run SWAT at the watershed scale for all watersheds in the United States (Arnold et al. 1999; Srinivasan et al. 1998). SWAT simulates the transport of water, sediment,

[9] The full theoretical and technical documentation of APEX can be found at http://epicapex.brc.tamus.edu/downloads/user-manuals.aspx .

[10] The I_APEX software steps through the simulations one at a time, extracting the needed data from the Access input tables, executes APEX, and then stores the model output in Access output files. The Web site for that software is http://www.card.iastate.edu/environment/interactive_programs.aspx.

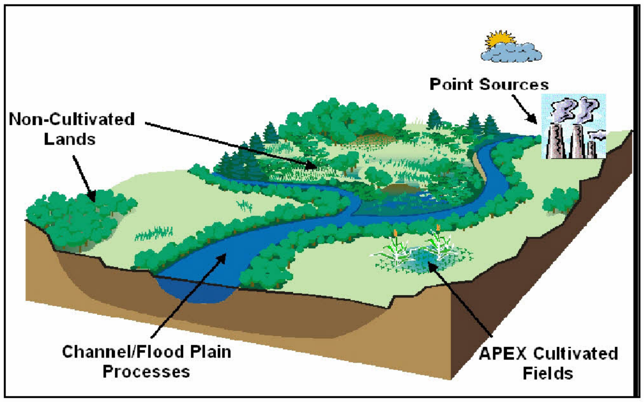
[11] Summaries of APEX model validation studies on how well APEX simulates measured data are presented in Gassman et al. (2009) and in "APEX Model Validation for CEAP" found at http://www.nrcs.usda.gov/technical/nri/ceap/Cropland.html.

[12] For a detailed description of the rules and procedures, see "Transforming Survey Data to APEX Model Input Files," http://www.nrcs.usda.gov/technical/nri/ceap/Cropland.html.

[13] For a detailed description of the rules and procedures for simulation of structural conservation practices, see "Modeling Structural Conservation Practices in APEX," http://www.nrcs.usda.gov/technical/nri/ceap/Cropland.html.

pesticides, and nutrients from the land to receiving streams and routes the flow downstream to the next watershed and ultimately to estuaries and oceans (figure 7).

**Figure 7.** Sources of water flows, sediment, and agricultural chemicals simulated with HUMUS/SWAT




Like APEX, SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007).[14] The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

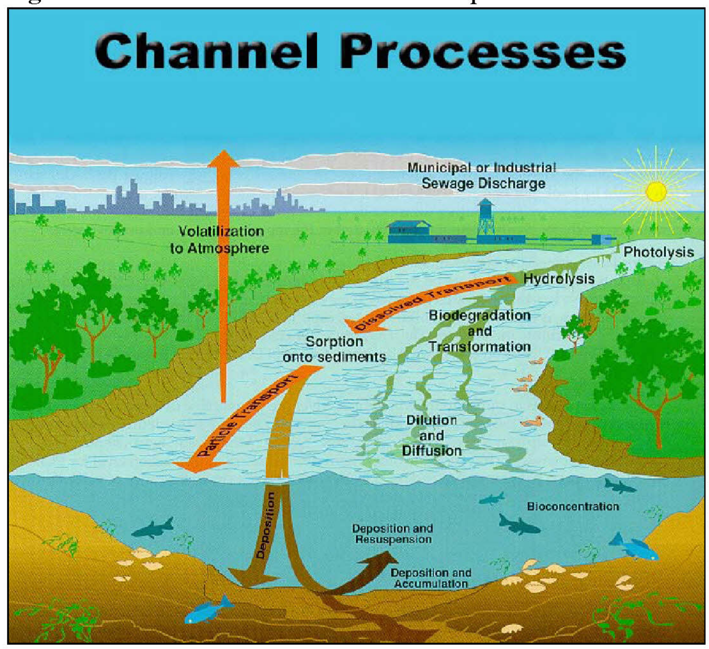
Source loads for cultivated cropland are estimated by APEX, and source loads for land uses other than cultivated cropland are estimated by SWAT. SWAT simulates the fate and transport of water, sediment, nutrients, and pesticides for the following land use categories, referred to as Hydrologic Response Units (HRUs):

- Pastureland
- Range shrub
- Range grass
- Urban
- Mixed forest
- Deciduous forest
- Evergreen forest
- Horticultural lands
- Forested wetlands
- Non-forested wetlands

All source loads, including point sources, are introduced into SWAT at the outlet of each watershed (8-digit hydrologic unit code [HUC]). Flows and source loads from upstream watersheds are routed through each downstream watershed, including reservoirs when present. During the routing, channel processes such as sediment deposition and degradation and nutrient and pesticide transformations are simulated (figure 8).[15]

Instream loads of sediment, nitrogen, phosphorus, and the pesticide atrazine are reported for each of the 4 subbasins (4-digit HUC) in the Chesapeake Bay region. Atrazine was the only pesticide modeled in the Chesapeake Bay region because of its dominance in determining environmental risk in the region.

**Figure 8.** SWAT model channel simulation processes




### Simulating the effects of weather

Weather is the predominant factor determining the loss of soil, nitrogen, phosphorus, and pesticides from farm fields, as well as the effects of conservation practices. To capture the effects of weather, each scenario was simulated using 47 years of actual daily weather data for the time period 1960 through 2006. The 47-year record is the extent of a serially complete daily data set of weather station data from weather station records available from the NCDC (National Climatic Data Center), for the period 1960 to 2006, including precipitation, temperature maximum, and temperature minimum (Eischeid et al., 2000). These data were combined with the respective PRISM (Parameter–Elevation Regressions on Independent Slopes Model; Daly et al., 1994) monthly map estimates to construct daily estimates of precipitation and temperature (Di Luzio et al., 2008). The same 47-year weather data were used in the HUMUS/SWAT simulations and in the APEX model simulations.

[14] A complete description of the SWAT model can be found at http://www.brc.tamus.edu/swat/index.html.

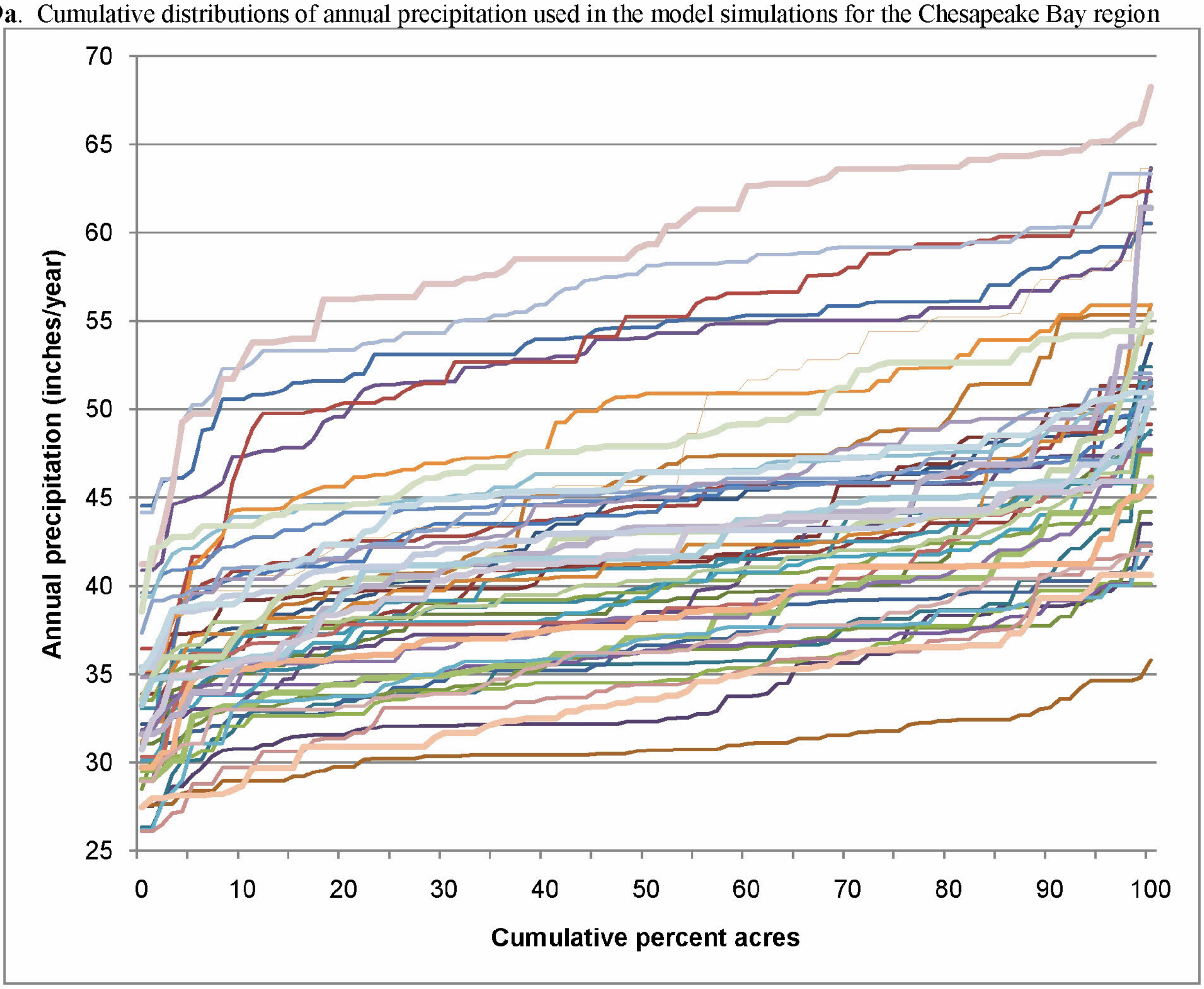
[15] For a complete documentation of HUMUS/SWAT as it was used in this study, as well as a summary of calibration and validation results for the Chesapeake Bay region, see "The CEAP-HUMUS National Water Quality Modeling System and Databases" at http://www.nrcs.usda.gov/technical/nri/ceap/Cropland.html.

Annual precipitation over the 47-year simulation averaged about 42 inches in this region. However, annual precipitation varied substantially in the model simulations, both within the region and from year to year, as shown in figures 9a and 9b. Each curve in figure 9a shows how annual precipitation varied over the region in one of the 47 years. The family of curves shows the variability from year to year.

The drier parts of the region received about 35 inches of precipitation per year, on average, and the wettest parts of the region received about 45 inches per year. Year-to-year variability is especially pronounced—the annual median precipitation amount (representing the region as a whole) ranged from 31 inches per year (1965) to 59 inches per year (2003) over the 47-years. The effects of conservation practices estimated in this study reflect these extreme conditions.

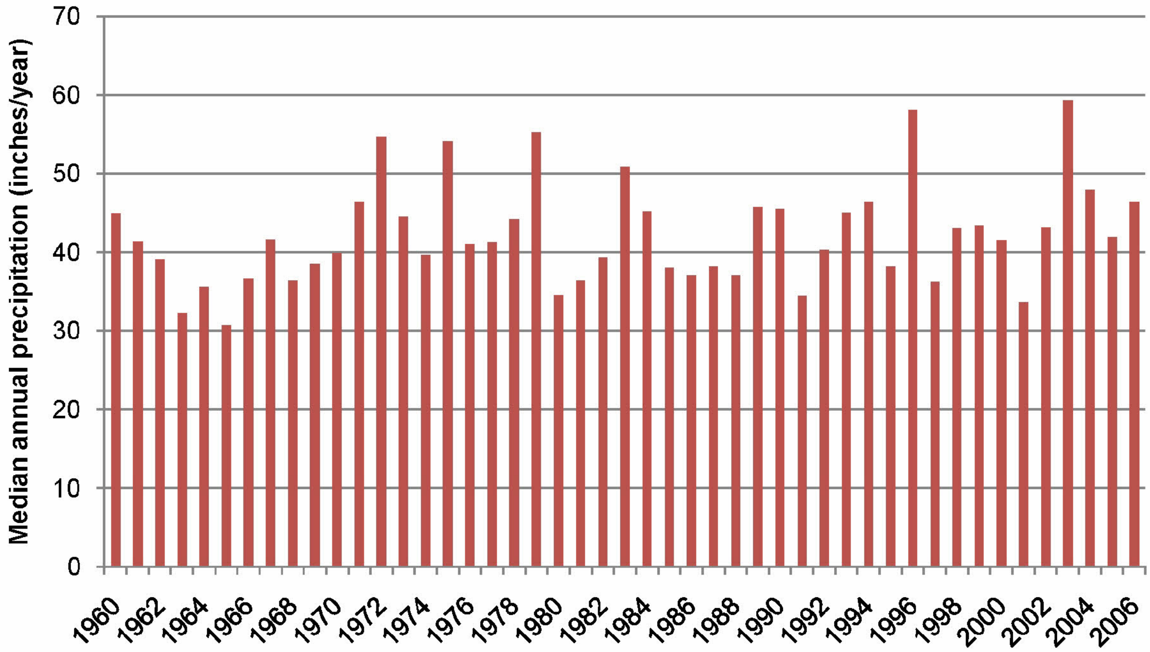
Because farming activities represent the time period 2003 to 2006, model results do not indicate environmental outcomes for each year of the 47 years. Rather, model results represent what would be expected to occur under varying weather conditions for farming activities conducted in the period 2003–06. For most analyses, model results are averaged over the 47 years and reported as average annual values. These average annual estimates thus represent environmental outcomes that would be expected over the long run.

**Figure 9a**. Cumulative distributions of annual precipitation used in the model simulations for the Chesapeake Bay region




**Note:** This figure shows how annual precipitation varied within the region and from year to year in the model simulation. Each of the 47 curves shown above represents a single year of data and shows how annual precipitation varied over the region in that year, starting with the driest acres within the region and increasing to the wettest acres for each year. The family of curves shows how annual precipitation varied from year to year. Annual precipitation over the 47-year simulation averaged about 42 inches. The top curve shown is for the year 2003, the wettest year in this region during the 47 years. The curve for 2003 shows that precipitation exceeded 56 inches for about 82 percent of cropped acres in the Chesapeake Bay region.

**Figure 9b**. Median annual precipitation used in the model simulations for the Chesapeake Bay region



### Simulating the no-practice scenario

The purpose of the no-practice scenario is to provide an estimate of the benefits of conservation practices in use within the Chesapeake Bay region. The only difference between the no-practice scenario and the baseline conservation condition is that the conservation practices are removed or their effects are reversed in the no-practice scenario simulations. There were usually several alternatives that could be used to represent "no practices." The no-practice representations derived for use in this study conformed to the following guidelines.

- **Consistency:** It is impossible to determine what an individual farmer would be doing if he or she had not adopted certain practices, so it is important to represent all practices on all sample points in a consistent manner that is based on the intended purpose of each practice.

- **Simplicity:** Complex rules for assigning "no-practice" activities lead to complex explanations that are difficult to substantiate and sometimes difficult to explain and accept. Complexity would not only complicate the modeling process but also hamper the interpretation of results.

- **Historical context avoided:** The no-practice scenario is a technological step backward for conservation, not a chronological step back to a prior era when conservation practices were not used. Although the advent of certain conservation technologies can be dated, the adoption of technology is gradual, regionally diverse, and ongoing. It is also important to retain the overall crop mix in the region, as it in part reflects today's market forces. Therefore, moving the clock back to 1950s (or any other time period) agriculture is not the goal of the no-practice scenario. Taking away the conservation ethic is the goal.

- **Moderation:** The no-practice scenario should provide a reasonable level of "poor" conservation so that a believable benefit can be determined, where warranted, but not so severe as to generate exaggerated conservation gains by simulating the worst-case condition. Tremendous benefits could be generated if, for example, nutrients were applied at twice the recommended rates with poor timing or application methods in the no-practice simulation. Similarly, large erosion benefits could be calculated if the no-practice representation for tillage was fall plowing with moldboard plows and heavy disking, which was once common but today would generally be considered economically inefficient.

- **Maintenance of crop yield or efficacy**. It is impossible to avoid small changes in crop yields, but care was taken to avoid no-practice representations that would significantly change crop yields and regional production capabilities. The same guideline was followed for pest control—the suite of pesticides used was not adjusted in the no-practice scenario because of the likelihood that alternative pesticides would not be as effective and would result in lower yields under actual conditions.

A deliberate effort was made to adhere to these guidelines to the same degree for all conservation practices so that the overall level of representation would be equally moderate for all practices. Table 6 summarizes the adjustments to conservation practices used in simulation of the no-practice scenario.

**No-practice representation of conservation tillage.** The no-practice tillage protocols are designed to remove the benefits of conservation tillage. For all crops grown with some kind of reduced tillage, including cover crops, the no-practice scenario simulates conventional tillage, based on the STIR (Soil Tillage Intensity Rating) value. Conventional tillage for the purpose of estimating conservation benefits is defined as any crop grown with a STIR value above 100. (To put this in context, no-till or direct seed systems have a STIR of less than 30, and that value is part of the technical standard for Residue Management, No-Till/Strip Till/Direct Seed [NRCS Practice Standard 329]). Those crops grown with a STIR value of less than 100 in the baseline conservation condition had tillage operations added in the no-practice scenario.

Simulating conventional tillage for crops with a STIR value of less than 100 requires the introduction of additional tillage operations in the field operations schedule. For the no-practice scenario, two consecutive tandem disk operations were added prior to planting. In addition to adding tillage, the hydrologic condition for assignment of the runoff curve number was changed from good to poor on all points receiving additional tillage. Points that are conventionally tilled for all crops in the baseline condition scenario are also modeled with a "poor" hydrologic condition curve number.

The most common type of tillage operation in the survey was disking, and the most common disk used was a tandem disk for nearly all crops, in all parts of the region, and for both dryland and irrigated agriculture. The tandem disk has a STIR value of 39 for a single use. Two consecutive disking operations will add 78 to the existing tillage intensity, which allows for more than 90 percent of the crops to exceed a STIR of 100 and yet maintain the unique suite and timing of operations for each crop in the rotation. Although a few sample points will have STIR values in the 80s or 90s after adding the two disking operations, the consistency of an across-the-board increase of 78 is simple and provides the effect of a distinctly more intense tillage system.

These additional two tillage operations were inserted in the simulation one week prior to planting, one of the least vulnerable times for tillage operations because it is close to the time when vegetation will begin to provide cover and protection.

**Table 6. Construction of the no-practice scenario**

| Practice adjusted | Level of criteria | Criteria used to determine if a practice was in use | Adjustment made to create the no-practice scenario |
|---|---|---|---|
| Residue management (tillage) | Crop within a crop year | STIR ≤100 | Add two tandem diskings 1 week prior to planting |
| Nitrogen rate – without manure | Crop within a crop year | Applied N ≤1.4 times harvest removal for non-legume crops | Increase rate to 2.06 times harvest removal (proportionate increase in all reported applications) |
| Phosphorus rate – without manure | Crop rotation | Applied P ≤1.1 times harvest removal for all crops in rotation | Increase rate to 2.0 times harvest removal (proportionate increase in all reported applications) |
| Nitrogen rate – with manure | Crop within a crop year | Applied total of fertilizer and manure N ≤1.4 times harvest removal for all crops | Increase manure and N fertilizer application rates to reach 2.06 times harvest removal (all applications increased proportionately) |
| Phosphorus rate – with manure | Crop rotation | Applied total of fertilizer and manure P ≤ 1.1 times harvest removal, accounting also for manure P associated with increase to meet nitrogen applications for no practice scenario | Increase P fertilizer application rates to reach 2.0 times harvest removal, accounting for increased manure due to the N criteria |
| Fertilizer application method | Application event | Incorporated or banded | Change to surface broadcast |
| Manure application method | Application event | Incorporated, banded, or injected | Change to surface broadcast |
| Fertilizer application timing | Application event | Within 3 weeks prior to planting, at planting, or within 60 days after planting. | Moved to 3 weeks prior to planting |
| Cover crop | Crop year | Cover crop planted for off-season protection | Remove cover crop simulation (field operations, fertilizer, grazing, etc.) |
| Pesticide | Sample | 1. Practicing high level of IPM | 1. All incorporated applications changed to surface application. For each crop, the first application event after planting and 30 days prior to harvest replicated twice, 1 week and 2 weeks later than original. |
| | | 2. Practicing moderate level of IPM | 2. Same as for high level of IPM, except replication of first application only 1 time, 1 week after original |
| Irrigation | Crop year | Pressure systems | Change to hand-move sprinkler system except where the existing system is less efficient |
| Structural practices | Sample | 1. Overland flow practices present<br>2. Concentrated flow—managed structures or waterways present<br>3. Edge-of-field mitigation practices present<br>4. Wind erosion control practices present | 1. USLE P-factor changed to 1 and slope length increased for points with terraces, soil condition changed from good to poor.<br>2. Structures and waterways replaced with earthen ditch, soil condition changed from good to poor.<br>3. Removed practice and width added back to field slope length.<br>4. Unsheltered distance increased to 400 meters |

**No-practice representation of structural practices.** The no-practice field condition for structural practices is simply the removal of the structural practices from the modeling process. In addition, the soil condition is changed from "Good" to "Poor" for the determination of the runoff curve number for erosion prediction.

- **Overland flow:** This group includes such practices as terraces and contouring which slow the flow of water across the field. For the practices affecting overland flow of water and therefore the P factor of the USLE-based equations, the P factor was increased to 1. Slope length is also changed for practices such as terraces to reflect the absence of these slope-interrupting practices.

- **Concentrated flow:** This group of practices is designed to address channelized flow and includes grassed waterways and grade stabilization structures. These practices are designed to prevent areas of concentrated flow from developing gullies or to stabilize gullies that have developed. The no-practice protocol for these practices removes the structure or waterway and replaces it with a "ditch" as a separate subarea. This ditch, or channel, represents a gully; however, the only sediment contributions from the gully will come from downcutting. Headcutting and sloughing of the sides are not simulated in APEX.

- **Edge of field:** These practices include buffers, filters, and other practices that occur outside the primary production area and act to mitigate the losses from the field. The no-practice protocol removes these areas and their management. When the practices are removed, the slope length is also restored to the undisturbed length that it would be if the practices were not in place. (When simulating a buffer in APEX, the slope length reported in the NRI is adjusted.)

- **Wind control:** Practices such as windbreaks or shelterbelts, cross wind ridges, stripcropping or trap strips, and hedgerows are examples of practices used for wind control. The unsheltered distance reflects the dimensions of the field as modeled, 400 meters or 1,312 feet. Any practices reducing the unsheltered distance are removed and the unsheltered distance set to 400 meters.

**No-practice representation of cover crops.** The no-practice protocol for this practice removes the planting of the crop and all associated management practices such as tillage and fertilization. In a few cases the cover crops were grazed; when the cover crops are removed so are the grazing operations.

**No-practice representation of nutrient management practices.** The no-practice nutrient management protocols are designed to remove the benefits of proper nutrient management techniques. The NRCS Nutrient Management standard (590) allows a variety of methods to reduce nutrient losses while supplying a sufficient amount of nutrient to meet realistic yield goals. The standard addresses nutrient loss in one of two primary ways: (1) by altering rates, form, timing, and methods of application, or (2) by installing buffers, filters, or erosion or runoff control practices to reduce mechanisms of loss. The latter method is covered by the structural practices protocols for the no-practice scenario. The goals of the nutrient management protocols are to alter three of the four basic aspects of nutrient application—rate, timing, and method. The form of application was not addressed because of the inability to determine if proper form was being applied.

- **Nitrogen rate:** For the no-practice scenario, the amount of commercial nitrogen fertilizer applied was increased to 2.06 times harvest removal for non-legume crops receiving less than or equal to 1.40 times the amount of nitrogen removed at harvest. The ratio of 2.06 for the increased nitrogen rate was determined by the average rate-to-yield-removal ratio for crops exceeding 1.4. Where nitrogen was applied in multiple applications, each application was increased proportionately. For sites receiving manure, the threshold for identifying good management was the total nitrogen application rate, both manure and fertilizer, and both fertilizer and manure were increased proportionately to reach the 2.06 times harvest removal threshold. The assessment for using appropriate nitrogen application rates was made on an average annual basis for each crop in the rotation using average annual model output for nitrogen removed at harvest in the baseline conservation condition scenario. *An exception to these rules is made for cotton.* A ratio of nitrogen added to nitrogen removed by lint at harvest of 2.8 is acceptable. For the no practice scenario, those receiving less than the 2.8 rate to yield ratio were not increased since cotton growth and yield is sensitive to over fertilization and would produce yield declines.

- **Phosphorus rate:** The no-practice scenario for phosphorus is similar to that for nitrogen, but with a lower threshold. The lower threshold was used because phosphorus is not lost through volatilization to the atmosphere and much less is lost through other pathways owing to strong bonding of phosphorus to soil particles. The threshold for identifying proper phosphorus application rates was 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest. For the no-practice scenario, the amount of phosphorus applied was increased to 2.0 times the harvest removal rate. (For crops receiving manure, any increase in phosphorus from manure added to meet the nitrogen criteria for no-practice was taken into account in setting the no-practice application rate.) The ratio of 2.0 for the increased phosphorus rate was determined by the average rate-to-yield-removal ratio for crops with phosphorus applications exceeding 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest. Multiple phosphorus applications were increased proportionately to meet the 2.0 threshold. No adjustment was made to manure applied at rates below the P threshold because the appropriate manure rate was based on the nitrogen level in the manure.

- **Timing of application**: Nutrients applied closest to the time when a plant needs them are the most efficiently utilized and least likely to be lost to the surrounding environment. All commercial fertilizer applications occurring within 3 weeks prior to planting, at planting, or within 60 days after planting were moved back to 3 weeks prior to planting for the no-practice scenario. For example, split applications that occur within 60 days after planting are moved to a single application 3 weeks before planting. Timing of manure applications was not adjusted in the no-practice scenario.

- **Method of application**: Nutrient applications, including manure applications, that were incorporated or banded were changed to a surface broadcast application method.

**No-practice representation of irrigation practices.** The no-practice irrigation protocols were designed to remove the benefits of better water management and the increased efficiencies of modern irrigation systems. Irrigation efficiencies are represented in APEX by a combination of three coefficients that recognize water losses from the water source to the field, evaporation losses with sprinkler systems, percolation losses below the root-zone during irrigation, and runoff at the lower end of the field. These coefficients are combined to form an over-all system efficiency that varies with soil type and land slope.

The quantity of water applied for all scenarios was simulated in APEX using an "auto-irrigation" procedure that applied irrigation water when the degree of plant stress exceeded a threshold. "Auto-irrigation" amounts were determined within pre-set single event minimums and maximums, and an annual maximum irrigation amount. APEX also used a pre-determined minimum number of days before another irrigation event regardless of plant stress.

In the no-practice representation, all conservation practices, such as Irrigation Water Management and Irrigation Land Leveling, were removed and samples with pressurized systems, such as center pivot, side roll, and low flow (drip), were changed to "hand move sprinklers," which represents an early form of pressure system. The "Big Gun" systems, which comprise 9.1 percent of the irrigated acres, are by and large already less efficient than the "hand move sprinklers," and most were not converted. However, 1.3 percent of the irrigated acres served by "Big Gun" systems are more efficient than the "hand move sprinklers," and these were converted in the no-practice representation. "Open discharge" gravity systems are used on approximately 5,300 acres or 2.5 percent of the irrigated area. The no-practice representation of gravity systems would use a ditch system with portals which is more efficient than the open discharge configuration, so these also were not converted.

For the no-practice scenario, the percentage of irrigated acreage with hand-move lines with impact sprinkler heads was increased to 89.7 percent (from 43.9 percent in the baseline conservation condition), 7.8 percent retained the Big Gun systems that were in use, and 2.5 percent were simulated with open discharge flood irrigation.

**No-practice representation of pesticide management practices.** Pesticide management for conservation purposes is a combination of three types of interrelated management activities:

1. A mix of conservation practices that retain pesticide residues within the field boundaries.
2. Pesticide use and application practices that minimize the risk that pesticide residue poses to the surrounding environment.
3. Practice of Integrated Pest Management (IPM) at a high level.

The first activity is covered by the no-practice representation of structural practices and residue and tillage management. The second activity, for the most part, cannot be simulated in large-scale regional modeling because of the difficulty in assuring that any changes in the types of pesticides applied or in the method or timing of application would provide sufficient protection against pests to maintain crop yields.[16] Farmers, of course, have such options, and environmentally conscientious farmers make tradeoffs to reduce environmental risk. But without better information on the nature of the pest problem both at the field level and in the surrounding area, modelers have to resort to prescriptive and generalized approaches to simulate alternative pesticides and application techniques, which would inevitably be inappropriate for many, if not most, of the acres simulated.

The no-practice representation for pesticide management is therefore based on the third type of activity—practicing IPM. An IPM indicator was developed on the basis of survey responses to IPM-related questions in the NRI-CEAP Cropland Survey.

Adoption of IPM systems normally occurs along a continuum from largely reliant on prophylactic control measures and pesticides to multiple-strategy, biologically intensive approaches, and is not usually an either/or situation. The practice of IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environment scenario. Where appropriate, each site should have in place a management strategy for **Prevention, Avoidance, Monitoring,** and **Suppression** of pest populations (the **PAMS** approach) (Coble, 1998). In order to qualify as IPM

[16] The APEX model can simulate pesticide applications, but it does not currently include a pest population model that would allow simulation of the effectiveness of pest management practices. Thus, the relative effectiveness of pesticide substitution or changes in other pest management practices cannot be evaluated.

practitioners, growers would use tactics in all four PAMS components.

**Prevention** is the practice of keeping a pest population from infesting a field or site, and should be the first line of defense. It includes such tactics as using pest-free seeds and transplants, preventing weeds from reproducing, irrigation scheduling to avoid situations conducive to disease development, cleaning tillage and harvesting equipment between fields or operations, using field sanitation procedures, and eliminating alternate hosts or sites for insect pests and disease organisms.

**Avoidance** may be practiced when pest populations exist in a field or site but the impact of the pest on the crop can be avoided through some cultural practice. Examples of avoidance tactics include crop rotation in which the crop of choice is not a host for the pest, choosing cultivars with genetic resistance to pests, using trap crops or pheromone traps, choosing cultivars with maturity dates that may allow harvest before pest populations develop, fertilization programs to promote rapid crop development, and simply not planting certain areas of fields where pest populations are likely to cause crop failure.

**Monitoring** and proper identification of pests through surveys or scouting programs, including trapping, weather monitoring and soil testing where appropriate, are performed as the basis for suppression activities. Records are kept of pest incidence and distribution for each field or site. Such records form the basis for crop rotation selection, economic thresholds, and suppressive actions.

**Suppression** of pest populations may be necessary to avoid economic loss if prevention and avoidance tactics are not successful. Suppressive tactics include *cultural* practices such as narrow row spacing or optimized in-row plant populations, alternative tillage approaches such as no-till or strip-till systems, cover crops or mulches, or using crops with allelopathic potential in the rotation. *Physical* suppression tactics include cultivation or mowing for weed control, baited or pheromone traps for certain insects, and temperature management or exclusion devices for insect and disease management. *Biological* controls, including mating disruption for insects, are alternatives to conventional pesticides, especially where long-term control of a troublesome pest species can be attained. Naturally occurring biological controls exist, where they exist, are important IPM tools. *Chemical pesticides* are applied as a last resort in suppression systems using a sound management approach, including selection of pesticides with low risk to non-target organisms.

An IPM index was developed to determine the level of IPM activity for each sample point. The index was constructed as follows:

- Scores were assigned to each question by a group of IPM experts.
- Scores for each PAMS category were normalized to have a maximum score of 100.
- The four PAMS categories were also scored in terms of relative importance for an IPM index: prevention = 1/6, avoidance = 1/6, monitoring = 1/3, and suppression = 1/3.
- The IPM indicator was calculated by multiplying the normalized PAMS category by the category weight and summing over the categories.

For samples classified as having either high or moderate IPM use, all soil-incorporated pesticide applications in the baseline condition were changed to surface applications. For high IPM cases, the first application event between planting and 30 days before harvest was replicated twice for each crop, one week and two weeks after its original application. For moderate IPM cases, the first application event was replicated one time for each crop, one week after its original application.

**No-practice representation of land in long-term conserving cover.** The no-practice representation of land in long-term conserving cover is cultivated cropping with no conservation practices in use. For each CRP sample point, a set of cropping simulations was developed to represent the probable mix of management that would be applied to the point if it were cropped. Cropped sample points were matched to each CRP sample point on the basis of slope, soil texture, soil hydrologic group, and geographic proximity. The cropped sample points that matched most closely were used to represent the cropped condition that would be expected at each CRP sample point if the field had not been enrolled in CRP. In most cases, seven "donor" points were used to represent the crops that were grown and the various management activities to represent crops and management for the CRP sample point "as if" the acres had not been enrolled in CRP. The crops and management activities of each donor crop sample were combined with the site and soil characteristics of the CRP point for the no-practice representation of land in long-term conserving cover.

# Chapter 3
# The Baseline Conservation Condition

## Overview and Summary of Findings

The use of conservation practices in the Chesapeake Bay region closely reflects the history of Federal conservation programs and technical assistance. In the beginning the focus was almost entirely on reducing soil erosion and the preserving the soil's productive capacity. In the 1930s and 1940s, Hugh Hammond Bennett, the founder and first chief of the Soil Conservation Service (now Natural Resources Conservation Service) instilled in the national ethic the need to treat every acre to its potential by controlling soil erosion and water runoff. Land shaping structural practices (such as terraces, contour farming, and strip cropping) and sediment control structures were widely adopted. Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. Conservation tillage, along with use of crop rotations and cover crops, was used either alone or in combination with structural practices to further reduce soil erosion on cropland. The conservation compliance provisions in the 1985 Farm Bill sharpened the focus to treatment of the most erodible acres, tying farm commodity payments to conservation treatment of highly erodible land. The Conservation Reserve Program was established to enroll the most erodible cropland acres in multi-year contracts to plant acres in long-term conserving cover.

During the 1990s, the focus of conservation efforts began to shift from soil conservation and sustainability to reducing pollution impacts associated with agricultural production. Prominent among new concerns were the environmental effects of nutrient export from farm fields. Traditional conservation practices used to control surface water runoff and erosion control were mitigating a significant portion of these nutrient losses. Additional gains were being achieved using nutrient management practices—application of nutrients (appropriate timing, rate, method, and form) to minimize losses to the environment and maximize the availability of nutrients for crop growth.

This study assessed the use and effectiveness of conservation practices in the Chesapeake Bay region for the period 2003 to 2006 to determine the baseline conservation condition for the region. The baseline conservation condition provides a benchmark for estimating the effects of existing conservation practices as well as projecting the likely effects of alternative conservation treatments. Conservation practices that were evaluated include structural practices, annual practices, and long-term conserving cover.

*Structural conservation practices*, once implemented, are usually kept in place for several years. Designed primarily for erosion control, they also mitigate edge-of-field nutrient and pesticide loss. Structural practices evaluated include—

- in-field practices for water erosion control, divided into two groups:
  - practices that control overland flow (terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping), and
  - practices that control concentrated flow (grassed waterways, grade stabilization structures, diversions, and other structures for water control);
- edge-of-field practices for buffering and filtering surface runoff before it leaves the field (riparian forest buffers, riparian herbaceous cover, filter strips, field borders); and
- wind erosion control practices (windbreaks/shelterbelts, cross wind trap strips, herbaceous wind barriers, hedgerow planting).

*Annual conservation practices* are management practices that are conducted as part of the crop production system each year. These practices are designed primarily to promote soil quality, reduce in-field erosion, and reduce the availability of sediment, nutrients, and pesticides for transport by wind or water. They include—

- residue and tillage management;
- nutrient management practices;
- pesticide management practices; and
- cover crops.

*Long-term conservation cover establishment* consists of planting suitable native or domestic grasses, forbs, or trees on environmentally sensitive cultivated cropland.

The effects of conservation crop rotation practices (NRCS practice code 328) were not assessed. This practice consists of growing different crops in a planned rotation to manage nutrient inputs, enhance soil quality, or reduce soil erosion. In the Chesapeake Bay region, crop rotations that meet NRCS criteria occur on about 77 percent of the cropped acres, often for reasons unrelated to conservation benefits, such as the control of pests or in response to changing markets. Estimating the effects of conservation crop rotation practices requires simulation of continuous cropping systems for all crops, for which adequate information on chemical use and other farming practices was not available.

Given the long history of conservation in the Chesapeake Bay region, it is not surprising to find that nearly all cropped acres in the region have evidence of some kind of conservation practice, especially erosion control practices. The conservation practice information collected during the study was used to assess the extent of conservation practice use. Key findings are:

- Structural practices for controlling water erosion are in use on 46 percent of cropped acres. On the 44 percent of the acres designated as highly erodible land, structural practices designed to control water erosion are in use on 63 percent of those acres.
- Reduced tillage is common in the region; 88 percent of the cropped acres meet criteria for either no-till (48

percent) or mulch till (40 percent). All but 7 percent of the acres had evidence of some kind of reduced tillage on at least one crop.

- About 40 percent of cropped acres are gaining soil organic carbon. An additional 36 percent of cropped acres are considered to be "maintaining" soil organic carbon (average annual loss less than 100 pounds per acre). Overall, 76 percent of cropped acres are maintaining or enhancing soil organic carbon.
- Producers use either residue and tillage management practices or structural practices, or both, on 96 percent of the acres.
- While most acres have evidence of some nitrogen or phosphorus management, the majority of the acres in the region lack consistent use of appropriate rates, timing, *and* method of application on each crop in every year of production, including nearly all of the acres receiving manure. For acres receiving nutrient applications, including manure—
  - Appropriate timing of nitrogen applications is in use on about 54 percent of the acres for all crops in the rotation.
  - About 32 percent of cropped acres meet criteria for appropriate nitrogen application rates for all crops in the rotation.
  - Appropriate nitrogen application rates, timing of application, and application method for all crops during every year of production, however, are in use on only about 12 percent of the acres.
  - Good phosphorus management practices (appropriate rate, timing, and method) are in use on 19 percent of the acres on all crops during every year of production.
- The Integrated Pest Management (IPM) indicator showed that only about 8 percent of the acres were being managed with a relatively high level of IPM.
- Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of about 100,000 acres in the region (2 percent of cultivated cropland), of which 67 percent is highly erodible land.

## Structural Conservation Practices

Data on structural practices for the farm field associated with each sample point were obtained from four sources:

1. **The NRI-CEAP Cropland Survey** included questions about the presence of 12 structural practices: terraces, grassed waterways, vegetative buffers (in-field), hedgerow plantings, riparian forest buffers, riparian herbaceous buffers, windbreaks or herbaceous wind barriers, contour buffers (in-field), field borders, filter strips, critical area planting, and grade stabilization structures.

2. For fields with conservation plans, **NRCS field offices** provided data on all structural practices included in the plans.

3. **The USDA-Farm Service Agency** (FSA) provided practice information for fields that were enrolled in the Continuous CRP for these structural practices: contour grass strips, filter strips, grassed waterways, riparian buffers (trees), and field windbreaks (Alex Barbarika, USDA/FSA, personal communication).

4. **The 2003 NRI** provided additional information for practices that could be reliably identified from overhead photography as part of the NRI data collection process. These practices include contour buffer strips, contour farming, contour stripcropping, field stripcropping, terraces, cross wind stripcropping, cross wind trap strips, diversions, field borders, filter strips, grassed waterways or outlets, hedgerow planting, herbaceous wind barriers, riparian forest buffers, and windbreak or shelterbelt establishment.

Overland flow control practices are designed to slow the movement of water across the soil surface to reduce surface water runoff and sheet and rill erosion. NRCS practice standards for overland flow control include terraces, contour farming, stripcropping, in-field vegetative barriers, and field borders. This is the most prevalent group of structural practices in the Chesapeake Bay region; these practices are found on about 34 percent of the cropped acres in the region; 51 percent of which are highly erodible land (table 7).

Concentrated flow control practices are designed to prevent the development of gullies along flow paths within the field. NRCS practice standards for concentrated flow control practices include grassed waterways, grade stabilization structures, diversions, and water and sediment control basins. These practices are found on about 17 percent of the cropped acres have one or more of these practices, including 29 percent of the highly erodible land.

Edge-of-field buffering and filtering practices, consisting of grasses, shrubs, and/or trees, are designed to capture the surface runoff losses that were not avoided or mitigated by the in-field practices. NRCS practice standards for edge-of-field mitigation practices include edge-of-field filter strips, riparian herbaceous buffers, and riparian forest buffers. CRP's buffer practices are included in this category. Edge-of-field buffering and filtering practices are in use on about 10 percent of all cropped acres in the region.

Wind erosion control practices are designed to reduce the force of the wind on the field. NRCS practice standards for wind erosion control practices include cross wind ridges, cross wind trap strips, herbaceous wind barriers, and windbreak/shelterbelt establishment. Wind erosion is not a resource concern for most acres in this region. Only about 7 percent of the cropped acres in the region are treated for wind erosion using structural practices.

**Table 7**. Structural conservation practices in use for the baseline conservation condition, Chesapeake Bay region

| Structural practice category | Conservation practice in use | Percent of non-HEL | Percent of HEL | Percent of cropped acres |
|---|---|---|---|---|
| Overland flow control practices | Terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping, field border, in-field vegetative barriers | 20 | 51 | 34 |
| Concentrated flow control practices | Grassed waterways, grade stabilization structures, diversions, other structures for water control | 8 | 29 | 17 |
| Edge-of-field buffering and filtering practices | Riparian forest buffers, riparian herbaceous buffers, filter strips | 12 | 8 | 10 |
| One or more water erosion control practices | Overland flow, concentrated flow, or edge-of-field practice | 33 | 63 | 46 |
| Wind erosion control practices | Windbreaks/shelterbelts, crosswind trap strips, herbaceous windbreak, hedgerow planting | 5 | 9 | 7 |

Note: About 44 percent of cropped acres in the Chesapeake Bay region are highly erodible land (HEL). Soils are classified as HEL if they have an erodibility index (EI) score of 8 or higher. A numerical expression of the potential of a soil to erode, EI considers the physical and chemical properties of the soil and climatic conditions where it is located. The higher the index, the greater the investment needed to maintain the sustainability of the soil resource base if intensively cropped.

Overall, about 46 percent of the cropped acres in the Chesapeake Bay region are treated with one or more water erosion control structural practices (table 7). The treated percentage for highly erodible land acres is higher—63 percent.

The structural conservation practices for water erosion control in use for each sample were classified as either a high level of treatment, moderately high level of treatment, moderate level of treatment, or low level of treatment. Criteria for each treatment level are presented in figure 10. These treatment levels are combined with soil risk classes to estimate acres that appear to be under-treated for water erosion control in chapter 6.

As shown in figure 10, only about 5 percent of cropped acres in the region have a high level of treatment (combination of edge-of-field buffering or filtering and at least one in-field structural practice). About 54 percent of the acres do not have structural practices for water erosion control; however, about 40 percent of these acres have slopes less than 2 percent, some of which may not need to be treated with structural practices.

## Residue and Tillage Management Practices

Simulations of the use of residue and tillage management practices were based on the field operations and machinery types reported in the NRI-CEAP Cropland Survey for each sample point. The survey obtained information on the timing, type, and frequency of each tillage implement used during the previous 3 years, including the crop to which the tillage operation applied.

The Soil Tillage Intensity Rating (STIR) (USDA-NRCS 2007)[17] was used to determine the soil disturbance intensity for each crop at each sample point. The soil disturbance intensity is a function of the kinds of tillage, the frequency of tillage, and the depth of tillage. STIR values were calculated for each crop and for each of the 3 years covered by the NRI-CEAP Cropland Survey (accounting for multiple crops or cover crops). By combining the STIR values for each crop year with model output on the long-term trend in soil organic carbon gain or loss, eight categories of residue and tillage management were identified, as defined in table 8.

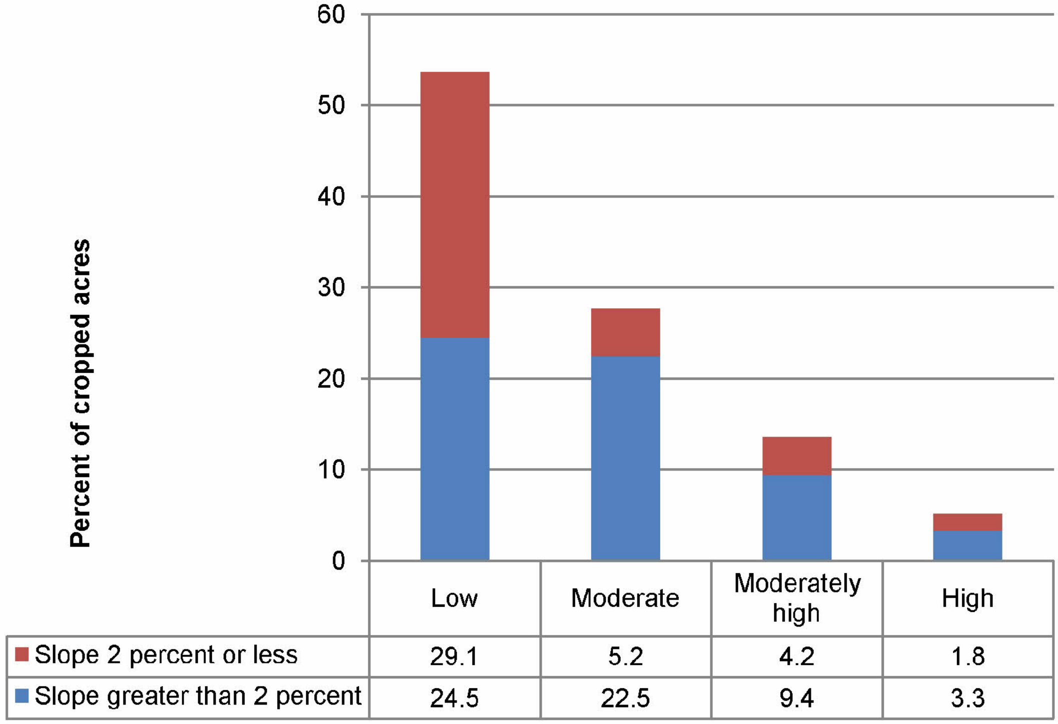
Overall, 88 percent of cropped acres in the Chesapeake Bay region meet the tillage intensity rating for no-till or mulch till (table 8). About 48 percent meet the criteria for no-till--25 percent with gains in soil organic carbon and 23 percent with soil organic carbon loss. About 40 percent meet the tillage intensity criteria for mulch till—13 percent with gains in soil organic carbon and 27 percent with soil organic carbon loss. No-till is used more frequently on highly erodible land than on non- highly erodible land. Only 7 percent of the acres are conventionally tilled for all crops in the rotation.

Four levels of treatment for residue and tillage management practices were derived according to criteria presented in figure 11. These treatment levels are combined with soil risk classes to estimate acres that appear to be under-treated for water erosion control in chapter 6. The high and moderately high treatment levels represent the 38 percent of the acres that meet tillage intensity criteria for either no-till or mulch till with gains in soil organic carbon. The high treatment level (32 percent of the acres) includes only those acres where the tillage intensity criteria are met for *each* crop in the rotation. The majority of the acres have a moderate level of treatment because soil organic carbon is not being enhanced. Only 6 percent of the acres have a low treatment level, consisting of continuous conventional tillage for all crops in the rotation and loss of soil organic carbon.

Most of the cropped acres (96 percent) in the Chesapeake Bay region have some kind of water erosion control practice—either reduced tillage or structural practices or both (table 9). About 41 percent meet tillage intensity for no-till or mulch till and have structural practices, including 57 percent of highly erodible land. Only 4 percent have no water erosion control practices.

[17] A description of the Soil Tillage Intensity Rating (STIR) can be found at http://stir.nrcs.usda.gov/.

**Figure 10**. Conservation treatment levels for structural practices, baseline conservation condition, Chesapeake Bay region




Criteria for four levels of treatment with structural conservation practices are:

- **High treatment**: Edge-of-field mitigation *and* at least one in-field structural practice (concentrated flow or overland flow practice) required.
- **Moderately high treatment**: Either edge-of-field mitigation required or both concentrated flow and overland flow practices required.
- **Moderate treatment**: No edge-of-field mitigation, either concentrated flow or overland flow practices required.
- **Low treatment**: No edge-of-field or in-field structural practices.

**Table 8.** Residue and tillage management practices for the baseline conservation condition, Chesapeake Bay region

| Residue and tillage management practice in use | Percent of non-HEL | Percent of HEL | Percent of all acres |
|---|---|---|---|
| Acres with carbon gain | 43 | 36 | 40 |
| Average annual tillage intensity for crop rotation meets criteria for no-till* | 25 | 24 | 25 |
| Average annual tillage intensity for crop rotation meets criteria for mulch till** | 15 | 10 | 13 |
| Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till | 2 | 1 | 1 |
| Continuous conventional tillage in every year of crop rotation*** | 2 | 1 | 2 |
| Acres with carbon loss | 57 | 64 | 60 |
| Average annual tillage intensity for crop rotation meets criteria for no-till* | 21 | 27 | 23 |
| Average annual tillage intensity for crop rotation meets criteria for mulch till** | 27 | 27 | 27 |
| Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till | 4 | 4 | 4 |
| Continuous conventional tillage in every year of crop rotation*** | 5 | 6 | 5 |
| All acres | | | |
| Average annual tillage intensity for crop rotation meets criteria for no-till* | 46 | 51 | 48 |
| Average annual tillage intensity for crop rotation meets criteria for mulch till** | 42 | 38 | 40 |
| Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till | 5 | 5 | 5 |
| Continuous conventional tillage in every year of crop rotation*** | 7 | 7 | 7 |

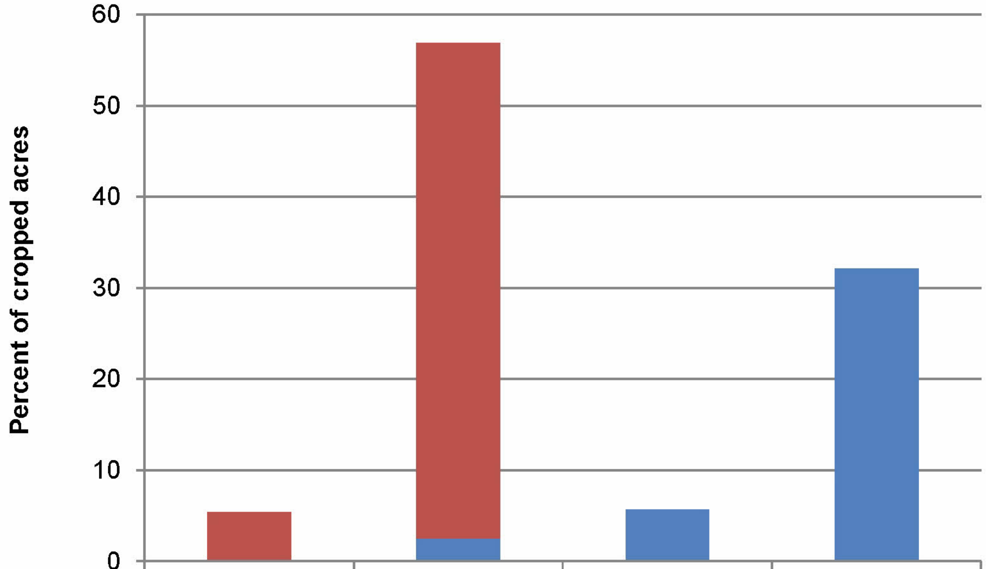
* Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is less than 30.
** Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is between 30 and 100.
*** Soil Tillage Intensity Rating (STIR) for every crop year in the rotation is more than 100.
HEL = highly erodible land.
Note: Percents may not add to totals because of rounding. About 44 percent of cropped acres in the Chesapeake Bay region are highly erodible land (HEL).

**Table 9**. Percent of cropped acres with water erosion control practices for the baseline conservation condition, Chesapeake Bay region

| Conservation treatment | Percent of non-HEL | Percent of HEL | Percent of all cropped acres |
|---|---|---|---|
| No-till or mulch till with carbon gain, no structural practices | 26 | 12 | 20 |
| No-till or mulch till with carbon loss, no structural practices | 33 | 20 | 27 |
| Some crops with reduced tillage, no structural practices | 3 | 2 | 2 |
| Structural practices and no-till or mulch till with carbon gain | 14 | 23 | 18 |
| Structural practices and no-till or mulch till with carbon loss | 14 | 34 | 23 |
| Structural practices and some crops with reduced tillage | 3 | 2 | 3 |
| Structural practices only | 2 | 4 | 3 |
| No water erosion control treatment | 5 | 3 | 4 |
| All acres | 100 | 100 | 100 |

Note: Percents may not add to totals because of rounding.

**Figure 11**. Conservation treatment levels for residue and tillage management, baseline conservation condition, Chesapeake Bay region




| | Low | Moderate | Moderately high | High |
|---|---|---|---|---|
| Losing carbon | 5.4 | 54.3 | 0.0 | 0.0 |
| Gaining carbon | 0.0 | 2.5 | 5.7 | 32.1 |

Criteria for four levels of treatment with residue and tillage management are:

- **High treatment**: *All crops* meet tillage intensity criteria for either no-till or mulch till and crop rotation is gaining soil organic carbon.
- **Moderately high treatment**: *Average annual* tillage intensity meets criteria for mulch till or no-till and crop rotation is gaining soil organic carbon; some crops in rotation exceed tillage intensity criteria for mulch till.
- **Moderate treatment**: Some crops have reduced tillage but do not meet criteria for high or moderately high treatment or crop rotation is gaining soil organic carbon; most acres in this treatment level are losing soil organic carbon.
- **Low treatment**: Continuous conventional tillage and crop rotation is losing soil organic carbon.

## Cover Crops

Cover crops are planted when the principal crops are not growing. The two most important functions of cover crops are (1) to provide soil surface cover and reduce soil erosion, and (2) to utilize and convert excess nutrients remaining in the soil from the preceding crop into plant biomass, thereby reducing nutrient leaching and minimizing the amount of soluble nutrients in runoff during the non-crop growing season. Cover crops also contribute to soil quality by capturing atmospheric carbon in plant tissue and adding it to the soil carbon.

The presence or absence of cover crops was determined from farmer responses in the NRI-CEAP Cropland Survey. The following criteria were used to identify a cover crop:

- A cover crop must be a close-grown crop that is not harvested as a principal crop, or if it is harvested, must have been specifically identified in the NRI-CEAP Cropland Survey as a cover crop as an indicator that the harvest was for an acceptable purpose (such as biomass removal or use as mulch or forage material). [18]
- Spring-planted cover crops are inter-seeded into a growing crop or are followed by the seeding of a summer or late fall crop that may be harvested during that same year or early the next year.
- Late-summer-planted cover crops are followed by the harvest of another crop in the same crop year or the next spring.
- Fall-planted cover crops are followed by the spring planting of a crop for harvest the next year.

Some cover crops are planted for soil protection during establishment of spring crops such as sugar beets and potatoes. Early spring vegetation protects young crop seedlings.

In the Chesapeake Bay region, cover crops were not commonly used as a conservation practice during the period covered by the farmer survey (2003-2006). Only about 4 percent of the acres (31 sample points) met the above criteria for a cover crop.

(Since the CEAP survey was conducted, participation in the Maryland Department of Agriculture cover crop program has increased substantially. As a result, cover crops are currently in wider use in Maryland than the CEAP survey shows for 2003-2006.)

## Irrigation Management Practices

Irrigation in the United States has it's roots in the arid West where precipitation is insufficient to meet the needs of growing crops. In much of the United States, though, rainfall totals are sufficient in most years to produce optimum yields of the crops grown. The distribution of the rainfall during the crop growing season is often problematic, as are those years when precipitation is below average. In the Chesapeake Bay region irrigation applications are sometimes used to supplement the natural rainfall.

Irrigation applications are made either with a pressure or a gravity system. Gravity systems, as the name implies, utilizes gravitational energy to move water from higher elevations to lower elevations, such as moving water from a ditch at the head of a field, across the field to the lower end. Pumps are most often used to create the pressure in pressure systems, and the water is applied under pressure through nozzles of one form or another. There are also many variations such as where water is diverted at higher elevations and the pressure created by gravity is substituted for the energy of a pump.

Proper irrigation involves applying appropriate amounts of water to the soil profile to reduce any plant stress while at the same time minimizing water losses through evaporation, deep percolation, and runoff. The conversion of much of the gravity irrigated area to pressure systems and the advent of pressure systems in rain-fed agricultural areas has reduced the volumes of irrigation water lost to deep percolation and end-of-field runoff, but has greatly increased the volume of water lost to evaporation in the sprinkling process. Modern sprinklers utilize improved nozzle technology to increase droplet size as well reduce the contact time from the nozzle to the ground. Irrigation specialists consider the center pivot or linear move sprinkler with low pressure heads as the current state of the art.

About 5 percent of the cropped acres—209,000 acres—receive irrigation water in the Chesapeake Bay region. Irrigation in the Chesapeake region is almost exclusively by pressure systems, however, some 5,300 acres or 2.5 percent of the irrigated area is served by gravity systems. Most common pressure systems are center-pivot or linear-move systems with impact sprinkler heads (43.9 percent) followed by center-pivot or linear-move systems with more efficient low-pressure spray or near-ground emitters (34 percent). Big gun sprinklers make up 9.1 percent. In the Chesapeake Bay Basin 80,800 acres or almost 39 percent of the irrigated acres already have systems with efficiencies at or better than the current state of the art.

## Nutrient Management Practices

Nitrogen and phosphorus are essential inputs to profitable crop production. Farmers apply these nutrients to the land as commercial fertilizers and manure to promote plant growth and increase crop yields. Not all of the nutrients applied to the land, however, are taken up by crops; some are lost to the environment and, when combined with naturally occurring levels of these elements, can create human health risks and other offsite environmental problems.

Sound nutrient management systems can minimize nutrient losses from the agricultural management zone while providing adequate soil fertility and nutrient availability to ensure realistic yields. (The agricultural management zone is defined as the zone surrounding a field that is bounded by the bottom

[18] Except for the 2003 survey, the questionnaire allowed the respondent to list the purpose for which a crop was grown, including cover crop. This information was not a reliable indicator of a cover crop for conservation purposes.

of the root zone, edge of the field, and top of the crop canopy.) Such systems are tailored to address the specific cropping system, nutrient sources available, and site characteristics of each field. All nutrient management systems have four basic criteria for application of commercial fertilizers and manure.

1. Apply nutrients at the **appropriate rate** based on soil and plant tissue analyses and realistic yield goals.
2. Apply the **appropriate form** of fertilizer and organic material with compositions and characteristics that resist nutrient losses from the agricultural management zone.
3. Apply at the **appropriate time** to supply nutrients to the crop when the plants have the most active uptake and biomass production, and avoid times when adverse weather conditions can result in large losses of nutrients from the agricultural management zone.
4. Apply using the **appropriate application method** that provides nutrients to the plants for rapid, efficient uptake and reduces the exposure of nutrient material to forces of wind and water.

Depending on the field characteristics, these nutrient management techniques can be coupled with other conservation practices such as conservation crop rotations, cover crops, residue management practices, and structural practices to minimize the potential for nutrient losses from the agricultural management zone. Even though nutrient transport and losses from agricultural fields cannot be completely eliminated, they can be minimized by careful management and kept within an acceptable level.

The presence or absence of nutrient management practices was based on information on the timing, rate, and method of application for manure and commercial fertilizer as reported by the producer in the NRI-CEAP Cropland Survey. The appropriate form of nutrients applied was not evaluated because the survey was not sufficiently specific about the material formulations that were applied. The following criteria were used to identify the appropriate rate, time, and method of nutrient application on a crop-by-crop basis:

- All commercial fertilizer and manure applications are within 3 weeks prior to plant date, at planting, or within 60 days after planting.
- The method of application for commercial fertilizer or manure is some form of incorporation or banding.
- Where only commercial fertilizer is applied—
  - the rate of commercial nitrogen fertilizer application is less than 1.4 times the amount of nitrogen removed in the crop yield at harvest; or
  - the rate of commercial phosphorus fertilizer application is less than 1.1 times the amount of phosphorus removed in the crop yield at harvest.
- Where manure is applied, the sum of the nitrogen in commercial fertilizer and the nitrogen in the manure is less than 1.4 times the amount of nitrogen removed in the crop yield at harvest. A nitrogen basis for manure applications is considered sufficient to meet requirements for nutrient management.[19]

These nutrient management criteria are intended to represent practice recommendations commonly found in nutrient management conservation plans. Some conservation plans have requirements that are less stringent, while others include more stringent nutrient management practices. The criteria used here to identify the occurrence of nutrient management practices, while generally consistent with NRCS standards, do not necessarily represent the best possible or even the best practical set of nutrient management practices.

As shown in table 10, the majority of acres with nutrients applied meet one or more of the criteria for nutrient management in the Chesapeake Bay region:

- 54 percent of cropped acres meet criteria for timing of nitrogen applications and 57 percent meet criteria for timing of phosphorus applications.
- 35 percent of cropped acres meet criteria for method of nitrogen application and 49 percent meet criteria for method of phosphorus application.
- 32 percent of cropped acres meet criteria for nitrogen application rate and 39 percent meet criteria for phosphorus application rate.

However, few acres meet all criteria. Overall, only 12 percent of the acres meet all criteria for nitrogen applications. Another 3 percent of cropped acres did not apply nitrogen. Proper phosphorus management is only slightly more common; 19 percent of the acres meet all criteria for phosphorus applications. About 7 percent of the acres did not apply phosphorus.

Only about 9 percent of cropped acres meet the criteria for *both* phosphorus and nitrogen management (table 10), including acres not receiving nutrient applications.
About 6 percent met all criteria with nitrogen rates less than 1.2 times removal at harvest for all crops, including acres not receiving nutrient applications.

[19] Meeting criteria for the more strict phosphorus basis for manure application was not evaluated. It is a common practice to use a nitrogen basis for manure application, which usually results in over-application of phosphorus. The farmers practicing sound phosphorus management then wait to apply manure again when soil tests show that phosphorus is needed. This prevents phosphorus from building up in the soil to levels that result in significant loss of soluble phosphorus in surface water runoff. It was not possible to determine this behavior from the survey responses.

**Table 10**. Nutrient management practices for the baseline conservation condition, Chesapeake Bay region

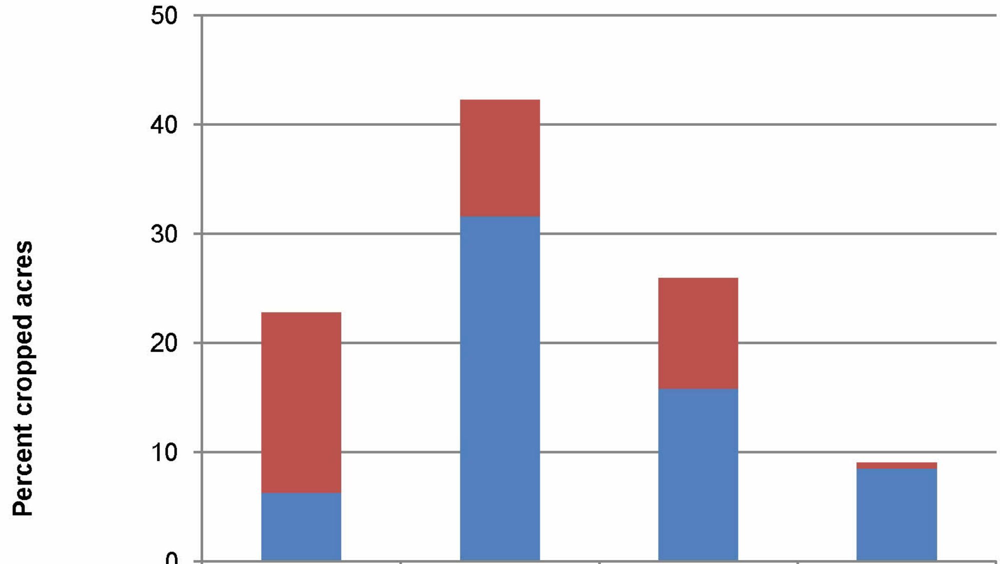
| | Percent of acres without manure applied | Percent of acres with manure applied | Percent of all cropped acres |
|---|---|---|---|
| **Nitrogen*** | | | |
| No N applied to any crop in rotation | 4 | 0 | 3 |
| For samples where N is applied: | | | |
| Time of application | | | |
| All crops in rotation have application of N (manure and/or fertilizer) within 3 weeks before planting or after planting | 77 | 16 | 54 |
| Some or all crops in rotation have fall application of N (manure and/or fertilizer) for spring planted crop | 8 | 37 | 19 |
| Some or all crops in rotation have application of N (manure and/or fertilizer) prior to 3 weeks before planting | 10 | 47 | 24 |
| Method of application | | | |
| All crops in rotation have N applied with incorporation or banding/foliar/spot treatment | 37 | 32 | 35 |
| Some crops in rotation have N applied with incorporation or banding/foliar/spot treatment | 45 | 67 | 53 |
| No crops in rotation have N applied with incorporation or banding/foliar/spot treatment | 14 | 0 | 9 |
| Rate of application | | | |
| All crops in rotation have N applied at a rate less than 1.4 times the removal in the yield at harvest** | 35 | 28 | 32 |
| Some crops in rotation have N applied at a rate less than 1.4 times the removal in the yield at harvest** | 55 | 58 | 56 |
| No crops in rotation have N applied at a rate less than 1.4 times the removal in the yield at harvest** | 6 | 14 | 9 |
| Timing and method and rate of application | | | |
| All crops have N rate less than 1.4 times removal at harvest and application within 3 weeks before planting or after planting with incorporation or banding/foliar/spot treatment | 17 | 3 | 12 |
| Some crops have N rate less than 1.4 times removal at harvest or application within 3 weeks before planting or after planting or use of incorporation or banding/foliar/spot treatment | 57 | 62 | 59 |
| No crops have N rate less than 1.4 times removal at harvest or application within 3 weeks before planting or after planting or use of incorporation or banding/foliar/spot treatment | 22 | 34 | 27 |
| **Phosphorus*** | | | |
| No P applied to any crop in rotation | 1 | 0 | 1 |
| For samples where P is applied: | | | |
| Time of application | | | |
| All crops in rotation have application of P (manure and/or fertilizer) within 3 weeks before planting or after planting | 82 | 17 | 57 |
| Some or all crops in rotation have fall application of P (manure and/or fertilizer) for spring planted crop | 8 | 36 | 18 |
| Some or all crops in rotation have application of P (manure and/or fertilizer) prior to 3 weeks before planting | 9 | 47 | 23 |
| Method of application | | | |
| All crops in rotation have P applied with incorporation or banding/foliar/spot treatment | 49 | 47 | 49 |
| Some crops in rotation have P applied with incorporation or banding/foliar/spot treatment | 37 | 53 | 43 |
| No crops in rotation have P applied with incorporation or banding/foliar/spot treatment | 12 | 0 | 7 |
| Rate of application | | | |
| Crop rotation has P applied at a rate less than 1.1 times the removal of P in the yield at harvest for the crop rotation | 51 | 18 | 39 |
| Crop rotation has P applied at a rate more than 1.1 times the removal of P in the yield at harvest for the crop rotation | 48 | 82 | 61 |
| Timing and method and rate of application | | | |
| Crop rotation has P rate less than 1.1 times removal at harvest and applications within 3 weeks before planting or after planting with incorporation or banding/foliar/spot treatment | 29 | 2 | 19 |
| Crop rotation has P rate less than 1.1 times removal at harvest and some crops had application within 3 weeks before planting or after planting and/or some crops used incorporation or banding/foliar/spot treatment | 19 | 12 | 16 |
| Crop rotation has P rate more than 1.1 times removal at harvest or no crops had applications within 3 weeks before planting or after planting or no crops used incorporation or banding/foliar/spot treatment | 51 | 85 | 64 |
| **Nitrogen and Phosphorus** | | | |
| Crop rotation P rate less than 1.1 and N rate less than 1.4 times removal at harvest and all applications within 3 weeks before planting or after planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied** | 14 | 1 | 9 |
| Crop rotation P rate less than 1.1 and N rate less than 1.2 times removal at harvest and all application within 3 weeks before planting or after planting with incorporation or banding/foliar/spot treatment , including acres with no N or P applied** | 9 | 1 | 6 |
| **All sample points** | 100 | 100 | 100 |

Note: About 38 percent of cropped acres (1.6 million acres) have manure applied. Percents may not add to 100 because of rounding.
* These estimates include adjustments made to the reported data on nitrogen and phosphorus application rates from the survey because of missing data and data-entry errors. In the case of phosphorus, the 3-year data period for which information was reported was too short to pick up phosphorus applications made at 4- and 5-year intervals between applications, which is a common practice for producers adhering to sound phosphorus management techniques. Since crop growth, and thus canopy development, is a function of nitrogen and phosphorus, it was necessary to add additional nitrogen and phosphorus when the reported levels were insufficient to support reasonable crop yields throughout the 47 years in the model simulation. The approach taken was to first identify crop samples that have application rates recorded erroneously or were under-reported in the survey. The model was used to identify these samples by running the simulation at optimal levels of nitrogen and phosphorus for crop growth. The set of crop samples identified were treated as if they had missing data. Additional nitrogen or phosphorus was added to these crop samples so that the total nitrogen or phosphorus use was similar to that for the unadjusted set of crop samples. About 30 percent of the acres received a nitrogen adjustment for one or more crops. About 25 percent of the acres received a phosphorus adjustment for one or more crops. Nitrogen and phosphorus were added by increasing the existing applications (thus preserving the reported timing and methods), when present, or were applied at plant.
** For cotton, a 2.8 ratio of nitrogen application to removal in the yield at harvest was used. There are only 89,000 acres of crop rotations that include cotton in the Chesapeake Bay region.

Four levels of treatment for nitrogen and phosphorus management were derived for use in evaluating the adequacy of nutrient management in the region. These treatment levels are combined with soil risk classes to estimate acres that appear to be under-treated in chapter 6. Criteria for the treatment levels are presented in figures 12 and 13. The high treatment level represents consistent use of appropriate rate, timing, and method for all crops. The high level of treatment for nitrogen additionally requires that application rates be equal to or less than 1.2 times the removal of nitrogen in crop yield at harvest to correspond to the higher standard simulated in the treatment scenarios presented in Chapter 7.

Based on these treatment levels, about 9 percent of the acres in the Chesapeake Bay region have a high level of nitrogen management and about 20 percent have a high level of phosphorus management (figures 12 and 13). Few acres with manure applied meet the criteria for the high treatment levels. About 65 percent of cropped acres have either low or moderate levels of nitrogen management, and 50 percent of the acres have either low or moderate levels of phosphorus management.

**Figure 12**. Conservation treatment levels for nitrogen management, baseline conservation condition, Chesapeake Bay region

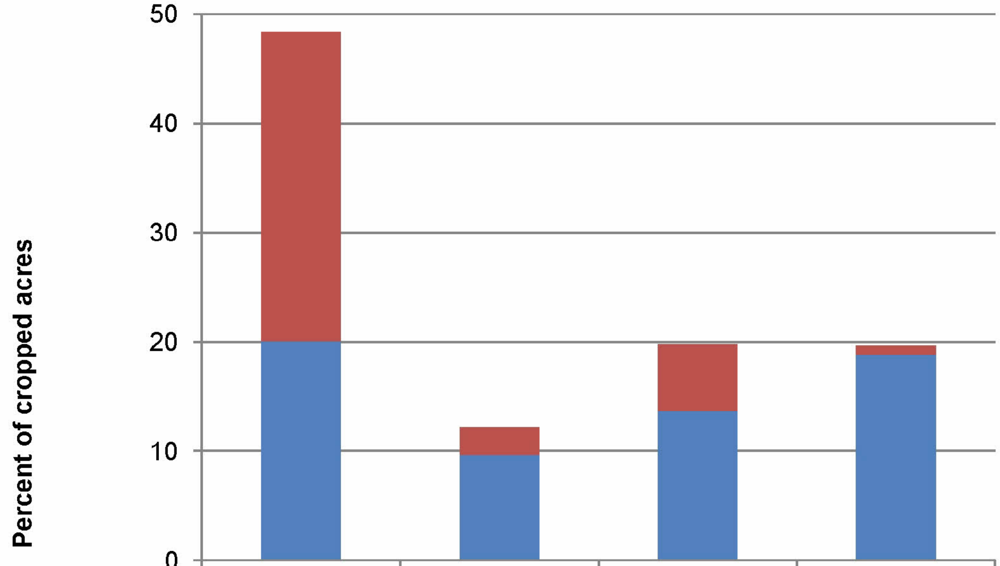



| | Low | Moderate | Moderately high | High |
|---|---|---|---|---|
| Manure applied | 16.5 | 10.6 | 10.2 | 0.5 |
| No manure applied | 6.3 | 31.7 | 15.8 | 8.5 |

Criteria for four levels of nitrogen management are:

- **High treatment**: All crops have (1) total nitrogen application rates (including manure) less than 1.2 times the nitrogen in the crop yield, (2) all applications occur within 3 weeks before planting or after planting, and (3) all applications are incorporated or banding/foliar/spot treatment is used. These criteria apply to both manure and commercial fertilizer applications.
- **Moderately high treatment**: Total nitrogen application rates (including manure) are less than 1.4 times the nitrogen in the crop yield for all crops. Timing and method of application criteria may not be met.
- **Moderate treatment**: All crops meet either the above criteria for timing *or* method, but do not meet criteria for rate.
- **Low treatment**: Some or all crops in rotation exceed criteria for rate and either timing or method.

**Figure 13**. Conservation treatment levels for phosphorus management, baseline conservation condition, Chesapeake Bay region




| | Low | Moderate | Moderately high | High |
|---|---|---|---|---|
| Manure applied | 28.3 | 2.5 | 6.1 | 0.8 |
| No manure applied | 20.1 | 9.6 | 13.7 | 18.8 |

Criteria for four levels of phosphorus management are:

- **High treatment**: (1) total phosphorus application rates (including manure) summed over all crops are less than 1.1 times the phosphorus in the crop yields for the crop rotation, (2) all applications occur within 3 weeks before planting or after planting, and (3) all applications are incorporated or banding/foliar/spot treatment was used. (Note that phosphorus applications for individual crops could exceed 1.1 times the phosphorus in the crop yield but total applications for the crop rotation could not.)
- **Moderately high treatment**: Total phosphorus application rates (including manure) are less than 1.1 times the phosphorus in the crop yield for the crop rotation. No application rate or timing of application criteria is applied.
- **Moderate treatment**: Sample points that do not meet the high or moderately high criteria but all phosphorus applications for all crops have appropriate time *and* method of application.
- **Low treatment**: All remaining sample points. All sample points have excessive application rates over the crop rotation and inadequate method or timing of application for at least one crop in the rotation.

## Pesticide Management Practices

The presence or absence of pesticide management practices was based on an Integrated Pest Management (IPM) indicator developed using producer responses to the set of IPM-related questions in the NRI-CEAP Cropland Survey, as discussed in chapter 2. Producer responses are summarized in table 11.

Four categories of IPM activities were scored separately: (1) prevention, (2) avoidance, (3) monitoring, and (4) suppression. After normalizing the scores for each category, the categories were combined into a single IPM score using a weight of 1/6 for prevention, 1/6 for avoidance, 1/3 for monitoring, and 1/3 for suppression. An IPM indicator score greater than 50 defined sample points with a high level of IPM activity. Sample points with an IPM indicator score of 25 to 50 were classified as moderately high IPM treatment and sample points with an IPM score less than 25 were classified as low IPM treatment.

About 8 percent of the acres in the Chesapeake Bay region have a high level of IPM activity (figure 14). About 44 percent have a moderate level of IPM activity, and 48 percent have a low level of IPM activity.

## Conservation Cover Establishment

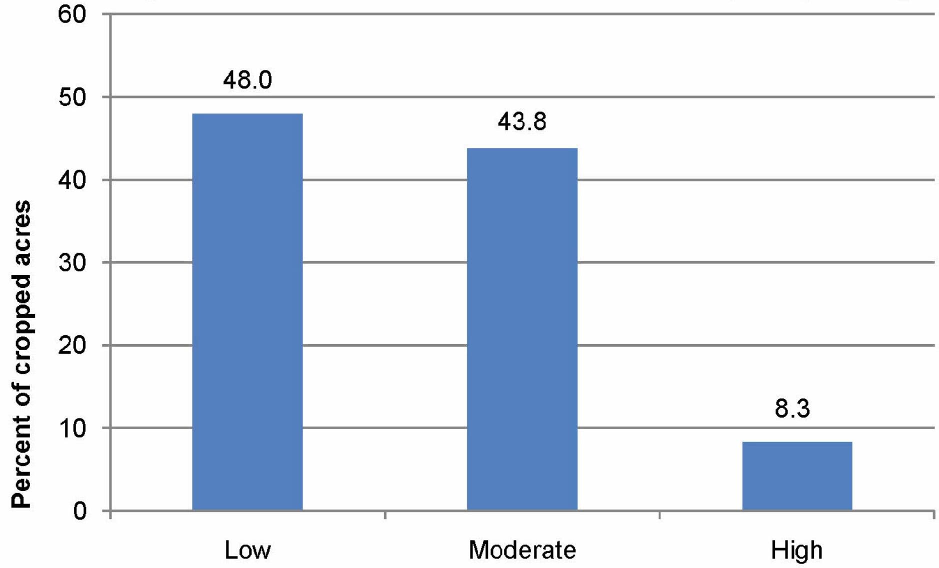
Establishing long-term cover of grass, forbs, or trees on a site provides the maximum protection against soil erosion. Conservation cover establishment is often used on cropland with soils that are vulnerable to erosion or leaching. The practice is also effective for sites that are adjacent to waterways, ponds, and lakes. Because these covers do not require annual applications of fertilizer and pesticides, this long-term conserving cover practice greatly reduces the loss of nitrogen and phosphorus from the site, and nearly eliminates pesticide loss. Because conservation covers are not harvested, they generate organic material that decomposes and increases soil organic carbon.

**Table 11.** Summary of survey responses to pest management questions, Chesapeake Bay region

| Survey question* | Score for corn and/or soybean crop mixes | Score for vegetable and tobacco crop system | Score for hay-crop mixes and other crop mixes | Number samples with "yes" response | Percent of cropped acres |
|---|---|---|---|---|---|
| **Prevention** | | | | | |
| Pesticides with different modes action rotated or tank mixed to prevent resistance | 5 | 5 | 3 | 252 | 33 |
| Chop, spray, mow, plow, burn field edges, etc. | 5 | 5 | 7 | 264 | 33 |
| Clean field implements after use | 5 | 5 | 5 | 272 | 35 |
| Highest possible score for prevention | 15 | 15 | 15 | | |
| **Avoidance** | | | | | |
| Rotate crops to manage pests | 8 | 10 | 0 | 531 | 66 |
| Use minimum till or no-till to manage pests | 6 | 0 | 0 | 482 | 56 |
| Choose crop variety that is resistant to pests | 6 | 6 | 0 | 299 | 34 |
| Planting locations selected to avoid pests | 3 | 4 | 0 | 109 | 12 |
| Plant/harvest dates adjusted to manage pests | 1 | 4 | 5 | 53 | 6 |
| Highest possible score for avoidance | 24 | 24 | 5 | | |
| **Monitoring** | | | | | |
| Scouting practice: general observations while performing routine tasks | 2 | 2 | 2 | 278 | 36 |
| Scouting practice: deliberate scouting | 10 | 10 | 10 | 366 | 44 |
| --Established scouting practice used | 4 | 4 | 4 | 156 | 19 |
| --Scouting due to pest development model | 2 | 2 | 2 | 62 | 8 |
| --Scouting due to pest advisory warning | 2 | 2 | 0 | 99 | 9 |
| Scouting done by: (only highest of the 4 scores is used) | | | | | |
| --Scouting by operator | 2 | 2 | 2 | 221 | 27 |
| --Scouting by employee | 2 | 2 | 2 | 2 | <1 |
| --Scouting by chemical dealer | 1 | 1 | 0 | 86 | 10 |
| --Scouting by crop consultant or commercial scout | 4 | 4 | 0 | 63 | 7 |
| Scouting records kept to track pests? | 4 | 4 | 4 | 140 | 17 |
| Scouting data compared to published thresholds? | 4 | 4 | 0 | 221 | 26 |
| Diagnostic lab identified pest? | 2 | 2 | 0 | 58 | 6 |
| Weather a factor in timing of pest management practice | 2 | 2 | 2 | 250 | 31 |
| Highest possible score for monitoring | 34 | 34 | 24 | | |
| **Suppression** | | | | | |
| Pesticides used? | 0 | 0 | 0 | 747 | 94 |
| Weather data used to guide pesticide application | 2 | 3 | 2 | 479 | 60 |
| Biological pesticides or products applied to manage pests | 0 | 4 | 0 | 87 | 9 |
| Pesticides with different mode of action rotated or tank mixed to prevent resistance | 5 | 5 | 0 | 252 | 33 |
| Pesticide application decision factor (one choice only): | | | | | |
| --Routine treatments or preventative scheduling | 0 | 0 | 0 | 393 | 50 |
| --Comparison of scouting data to published thresholds | 3 | 3 | 3 | 67 | 8 |
| --Comparison of scouting data to operator's thresholds | 2 | 2 | 2 | 71 | 8 |
| --Field mapping or GPS | 2 | 2 | 2 | 2 | 0 |
| --Dealer recommendations | 2 | 2 | 2 | 112 | 13 |
| --Crop consultant recommendations | 4 | 4 | 4 | 54 | 8 |
| --University extension recommendations | 3 | 3 | 3 | 5 | 1 |
| --Neighbor recommendations | 0 | 0 | 0 | 1 | <1 |
| --"Other" | 0 | 0 | 0 | 13 | 2 |
| Maintain ground covers, mulch, or other physical barriers | 4 | 5 | 6 | 317 | 41 |
| Adjust spacing, plant density, or row directions | 4 | 4 | 6 | 153 | 16 |
| Release beneficial organisms | 0 | 4 | 0 | 13 | 1 |
| Cultivate for weed control during the growing season | 2 | 3 | 0 | 42 | 6 |
| Risk level of suite of pesticides used, based on human toxicities* | | | | | |
| Risk in lowest 1/3 of acres | 10 | 10 | 10 | 227 | 32 |
| Risk in middle 1/3 of acres | 5 | 5 | 5 | 257 | 34 |
| Risk in highest 1/3 of acres | 0 | 0 | 0 | 287 | 34 |
| Risk level of suite of pesticides used, based on aquatic ecosystem toxicities* | | | | | |
| Risk in lowest 1/3 of acres | 10 | 10 | 10 | 233 | 33 |
| Risk in middle 1/3 of acres | 5 | 5 | 5 | 271 | 34 |
| Risk in highest 1/3 of acres | 0 | 0 | 0 | 267 | 33 |
| Highest possible score for suppression | 41 | 52 | 38 | | |

Note: The scores shown in this table were used to develop an IPM indicator as discussed in the text.
* Edge-of-field risk indicators were based on pesticide loss from fields as determined from model output.

**Figure 14**. Integrated Pesticide Management indicator for the baseline conservation condition, Chesapeake Bay region




Note: The Integrated Pest Management (IPM) indicator was developed using responses to questions in the NRI-CEAP Cropland survey on pest and pesticide management as described in the text.

For this study, the effect of a long-term conserving cover practice was estimated using acres enrolled in the General Signup of the CRP. The CRP General Signup is a voluntary program in which producers with eligible land enter into 10- to 15-year contracts to establish long-term cover to reduce soil erosion, improve water quality, and enhance wildlife habitat.

Landowners receive annual rental payments and cost-share assistance for establishing and maintaining permanent vegetative cover. To be eligible for enrollment in the CRP General Signup, the field (or tract) must meet specified crop history criteria.

Other factors governing enrollment in the CRP include natural resource-based eligibility criteria, an Environmental Benefits Index (EBI) used to compare and rank enrollment offers, acreage limits, and upper limits on the proportion of a county's cropland that can be enrolled (USDA Farm Service Agency 2004; Wiebe and Gollehon 2006). Initially, the eligibility criteria included only soil erosion rates and inherent soil erodibility. During the 1990s and to date, the eligibility criteria have continued to evolve, with increasing emphasis placed on issues other than soil erodibility. For contract offer ranking, weight was given to proposals that also benefited wildlife, air and water quality, and other environmental concerns.

As of 2006, about 32 million acres were enrolled in the CRP General Signup nationally, including about 100,000 in the Chesapeake Bay region. Approximately two-thirds of the cropland acres enrolled in the CRP in the Chesapeake Bay region is classified as highly erodible land. The inclusion of non-highly erodible land is due to both the expansion of enrollment eligibility criteria beyond soil erosion issues and the fact that farmers were allowed to enroll entire fields in the CRP if a specified portion of the field (varied by signup and eligibility criterion) met the criteria.

In the Chesapeake Bay region, 65 percent of the CRP land is planted to introduced grasses, 29 percent to trees, 5 percent to wildlife habitat and 1 percent to native grasses. The plantings designated in the NRI database for each sample point were simulated in the model. However, in all cases the simulated cover was a mix of species and all points included at least one grass and one clover species.

# Chapter 4
# Onsite (Field-Level) Effects of Conservation Practices

## Water

Water is a potent force that interacts with or drives almost all environmental processes acting within an agricultural production system. The hydrologic conditions prevalent in the Chesapeake Bay region are critical to understanding the estimates of sediment, nutrient, and pesticide loss presented in subsequent sections. The APEX model simulates hydrologic processes at the field scale—precipitation, irrigation, evapotranspiration, surface water runoff, infiltration, and percolation beyond the bottom of the soil profile.

Precipitation and irrigation are the sources of water for a field. Annual precipitation over the 47-year simulation averaged about 42 inches in this region (table 12). (Also see figure 9a and 9b.) Only about 5 percent of the cultivated cropland acres are irrigated, at an average annual application of 13 inches.

Most of the water that leaves the field is lost through evaporation and transpiration (evapotranspiration) (figure 15). On average, about 63 percent of the water loss from cultivated cropland and land in long-term conserving cover in the Chesapeake Bay region is through evapotranspiration (table 12). Evapotranspiration is the dominant loss pathway for 98 percent of cropped acres. Evapotranspiration losses vary, however, according to soil characteristics and land cover. In the Chesapeake Bay region, evapotranspiration ranges from about 40 percent to 80 percent of the total amount of water that leaves the field (figure 16).

Loss of water through subsurface flow pathways is the second largest source of water loss at an average of about 11.5 inches per year for cropped acres and 15 inches per year for land in long-term conserving cover. Subsurface flow pathways include: (1) percolation through the soil profile, (2) subsurface flow into a tile or ditch drainage system, (3) groundwater return flow, (4) lateral subsurface outflow, and (5) quick-return subsurface flow. The percentage of water loss represented by subsurface flows averages about 26 percent for cropped acres and 35 percent for land in long-term conserving cover. However, this percentage is highly variable for cropped acres in the Chesapeake Bay region, as shown in figure 16.

Surface water runoff averages about 10 percent of water loss from fields for cropped acres and 5 percent for land in long-term conserving cover (table 12). The percentage ranges from zero to about 26 percent for cropped acres in the Chesapeake Bay region (figure 16).

Structural water erosion control practices, residue management practices, and reduced tillage slow the flow of surface water runoff and allow more of the water to infiltrate into the soil. Model simulations indicate that conservation practices have reduced surface water runoff by about 0.9 inch per year averaged over all acres, representing a 17-percent reduction for the region (table 12).

The re-routing of surface water to subsurface flows is shown graphically in figures 17, 18, and 19 for cropped acres. The amount of surface water runoff varies from acre to acre, ranging from an annual average of 1 inch per year for some acres to over 10 inches per year. Surface water runoff is highest for acres with higher slopes, soil properties conducive to runoff, and higher precipitation. Similarly, subsurface flows vary from acre to acre (figure 18). The no-practice scenario curves in figures 17 and 18 show what the distribution of surface water runoff and subsurface flows would be if there were no conservation practices in use—less subsurface flow and more surface water runoff.

Model simulations further show that land in long-term conserving cover (baseline conservation condition) in the region has, on average, about half the surface water runoff and more subsurface flow than would occur if the land was cropped (table 12). The distribution of surface water runoff for the baseline conservation condition and the no-practice scenario (simulating a cropped condition) for acres in long-term conserving cover are compared in figure 20.

The variability in the effects of conservation practices in re-routing surface water to subsurface flows is shown in figure 19 for cropped acres and figure 21 for land in long-term conserving cover. For cropped acres, reductions in surface water runoff range up to 3 inches per year due to conservation practice use. This variability reflects different levels of conservation treatment as well as differences in precipitation and inherent differences among acres for water to run off.

Reductions in surface water runoff reduce the loss of nutrients and pesticides exported to the surrounding environment through overland flow. However, the increase in infiltration also re-directs nutrients and pesticides in solution to subsurface loss pathways. Consequently, careful management of nutrients and pesticides is required to offset this re-routing of pollutants when water erosion control practices are used.

Use of improved irrigation systems in the Chesapeake Bay region increases over-all system efficiency from 42 percent in the no-practice scenario to 68 percent in the baseline scenario. This change in efficiency represents an annual decreased need of water diversions of 11 inches per irrigated acre (table 12).

**Figure 15.** Estimates of average annual water lost through three loss pathways for cropped acres in the Chesapeake Bay region

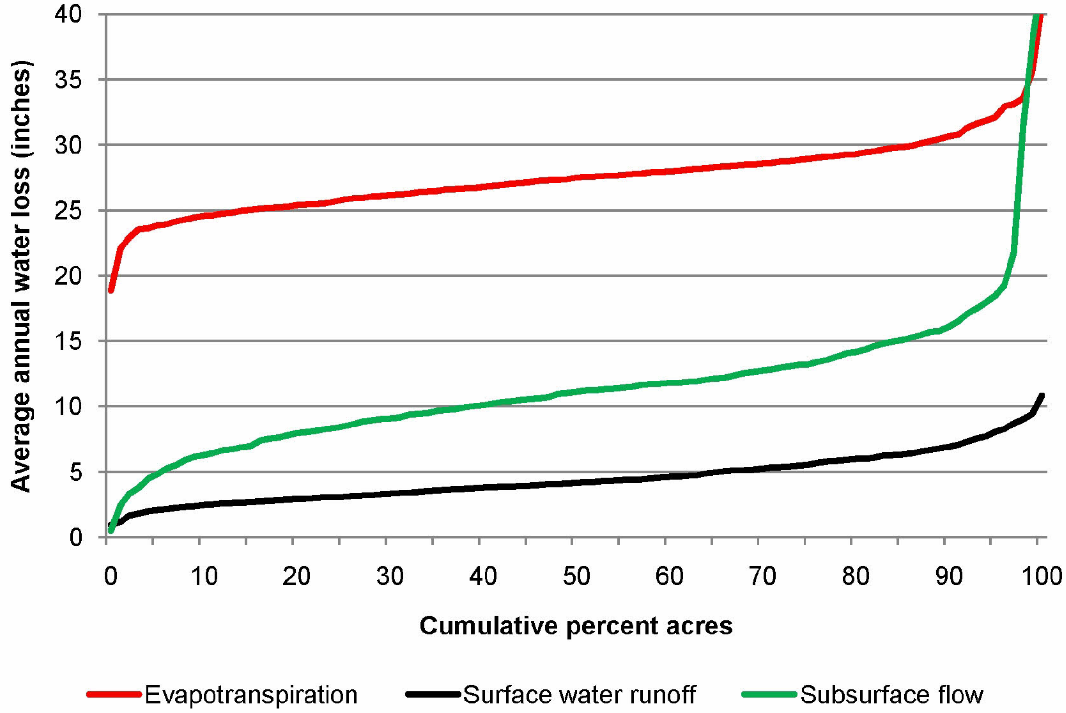



**Figure 16.** Cumulative distributions of the proportion of water lost through three loss pathways, Chesapeake Bay region

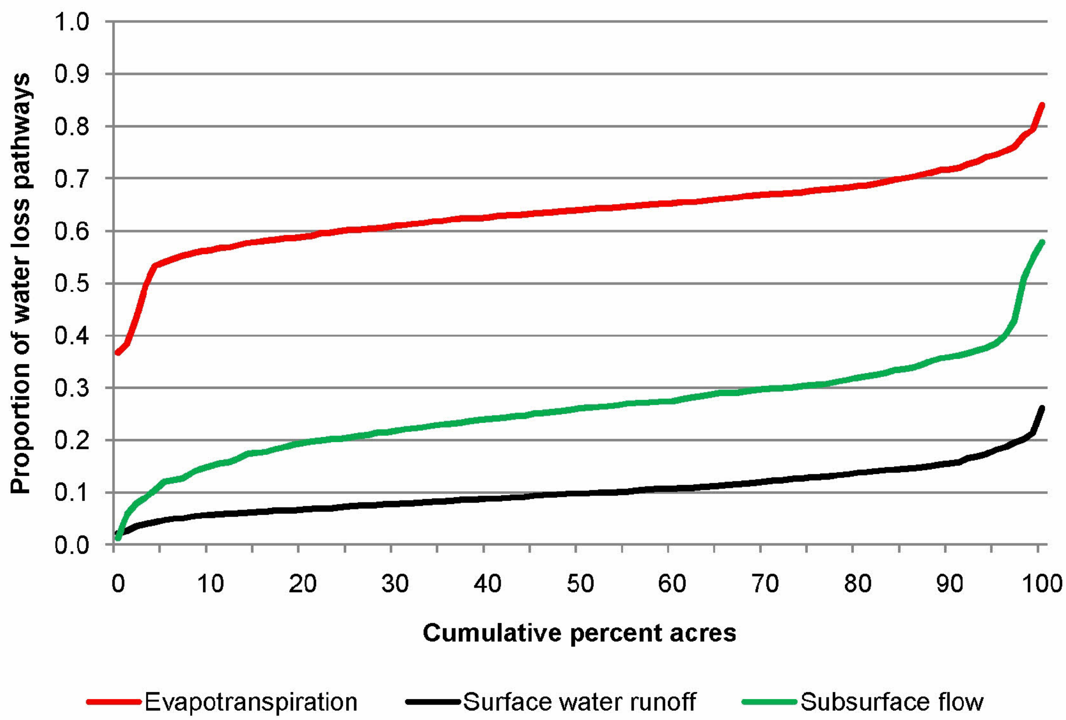


**Table 12**. Field-level effects of conservation practices on water loss pathways for cultivated cropland in the Chesapeake Bay region

| Model simulated outcome | Baseline conservation condition | No-practice scenario | Reduction due to practices | Percent reduction |
|---|---|---|---|---|
| **Cropped acres (4.3 million acres)** | | | | |
| **Water sources*** | | | | |
| Non-irrigated acres | | | | |
| Average annual precipitation (inches) | 42.2 | 42.2 | 0.0 | 0 |
| Irrigated acres | | | | |
| Average annual precipitation (inches) | 42.8 | 42.8 | 0.0 | 0 |
| Average annual irrigation water applied (inches) | 13.1 | 24.0 | 11.0 | 46 |
| **Water loss pathways** | | | | |
| Average annual evapotranspiration (inches) | 27.6 | 27.7 | 0.1 | 0 |
| Average annual surface water runoff (inches) | 4.5 | 5.4 | 0.9 | 17 |
| Average annual subsurface water flows (inches)** | 11.5 | 10.6 | -0.9*** | 9 |
| **Land in long-term conserving cover (0.1 million acres)** | | | | |
| **Water sources*** | | | | |
| Average annual precipitation (inches) | 41.9 | 41.9 | 0.0 | 0 |
| Average annual irrigation water applied (inches)* | 0.0 | 0.1 | 0.1 | 100 |
| **Water loss pathways** | | | | |
| Average annual evapotranspiration (inches) | 25.4 | 26.4 | 1.0 | 4 |
| Average annual surface water runoff (inches) | 2.1 | 5.4 | 3.3 | 61 |
| Average annual subsurface water flow (inches)** | 14.6 | 10.4 | -4.2 | -41 |

* About 5 percent of the cropped acres in the Chesapeake Bay region are irrigated. Land in long-term conserving cover was not irrigated, but some farming practices used to simulate a cropped condition to represent the no-practice scenario included irrigation. Values shown in the table for land in long-term conserving cover are averages over all acres, including non-irrigated acres.

** Subsurface flow pathways include (1) percolation through the soil profile, (2) subsurface flow into a drainage system, (3) groundwater return flow, (4) lateral subsurface outflow, and (5) quick-return subsurface flow.

*** Represents an average gain in subsurface flows of 0.9 inch per year (9 percent increase) due to the use of conservation practices.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Note: Model simulation results for the baseline conservation condition are presented in appendix C for the 4 subbasins.

**Figure 17.** Estimates of average annual surface water runoff for cropped acres in the Chesapeake Bay region

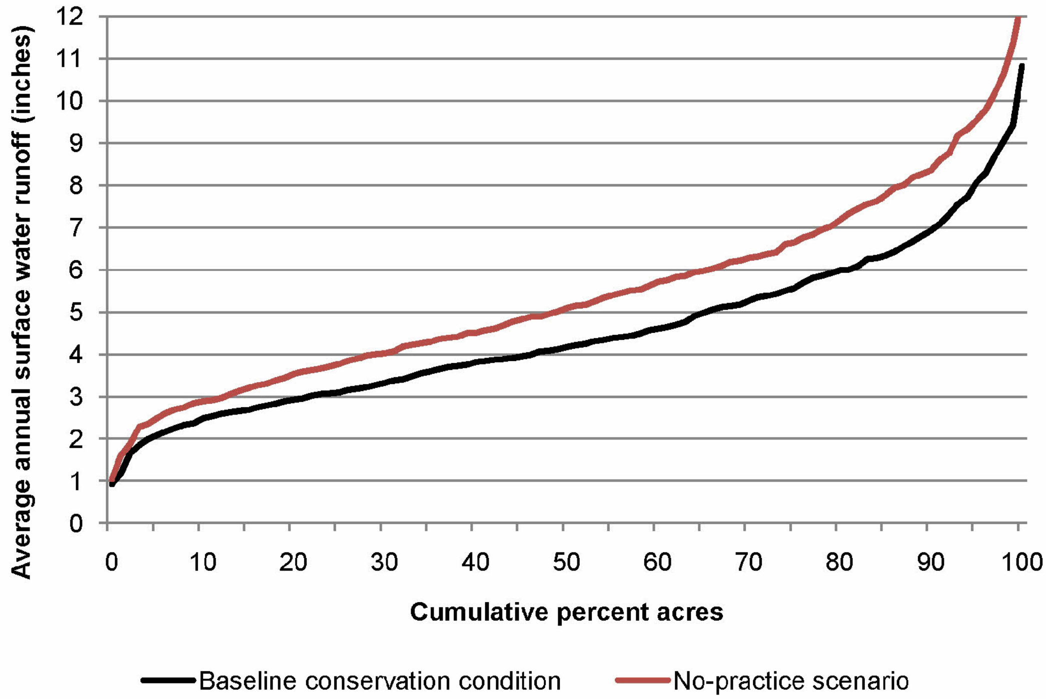



**Figure 18**. Estimates of average annual subsurface flows for cropped acres in the Chesapeake Bay region

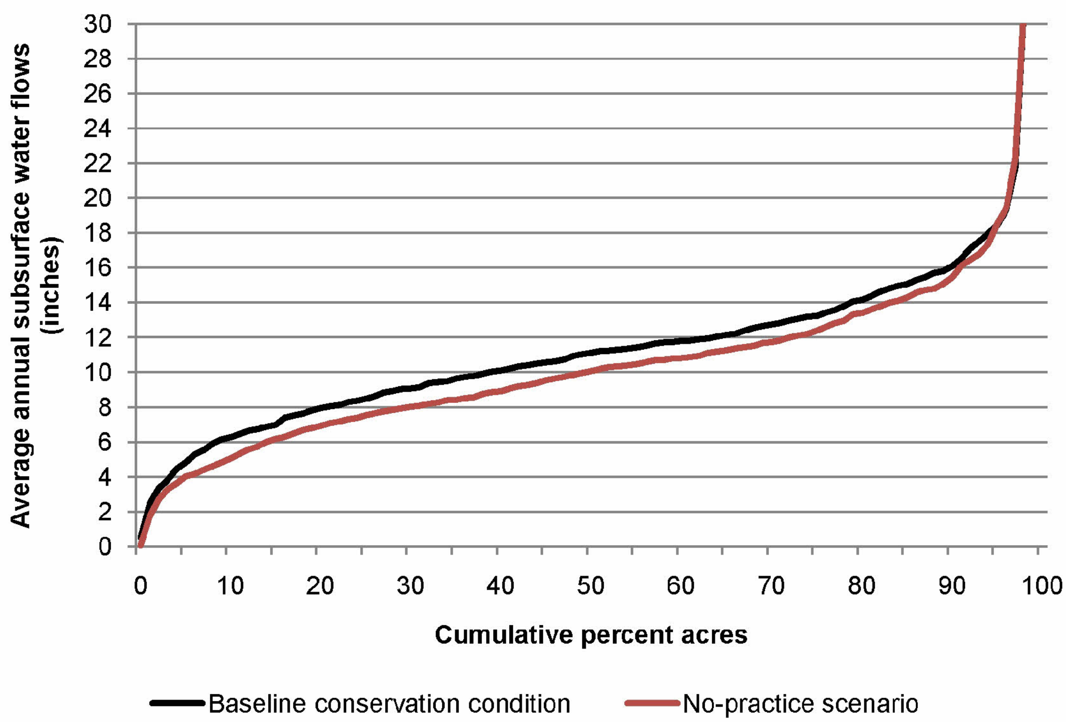
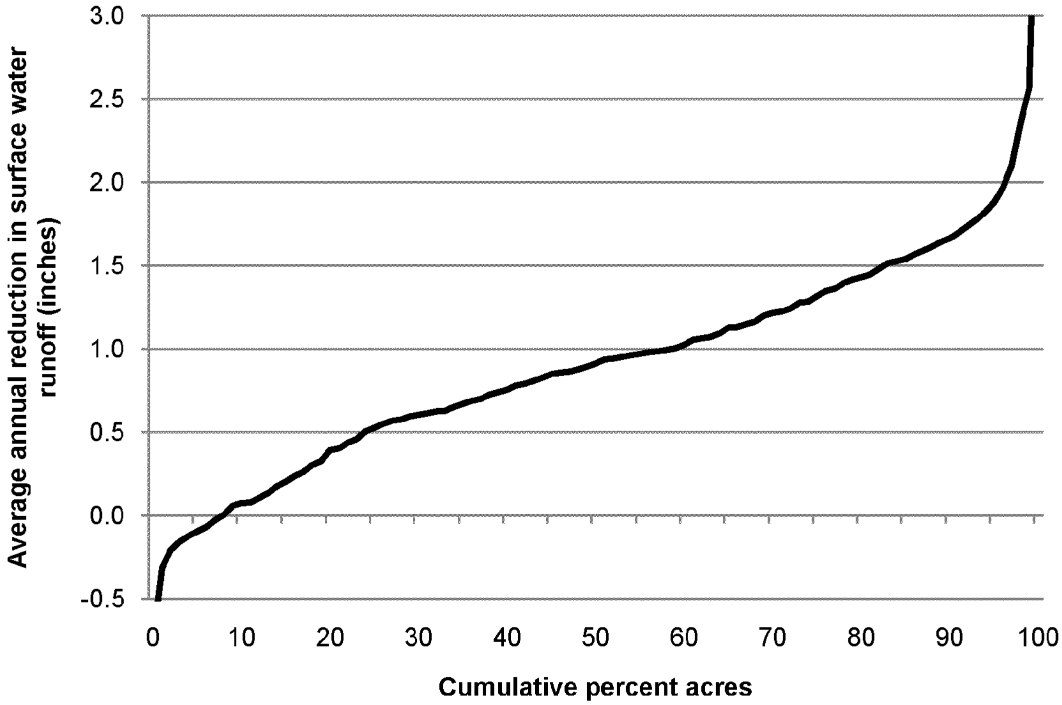


**Figure 19**. Estimates of average annual reduction in surface water runoff due to the use of conservation practices on cropped acres in the Chesapeake Bay region




Note: About 7 percent of the acres had less surface water runoff in the no-practice scenario than the baseline conservation condition. In general, these gains in surface water runoff due to practices occur on soils with low to moderate potential for surface water runoff together with (1) higher nutrient application rates in the no-practice scenario that result in more biomass production, which can reduce surface water runoff (typically rotations with hay or continuous corn); or (2) the additional tillage simulated in the no-practice scenario provided increased random roughness of the surface reducing runoff on nearly level landscapes with low crop residue rotations.

## Cumulative Distributions Show How Effects of Conservation Practices Vary Throughout the Region

The design of this study provides the opportunity to examine not only the overall mean value for a given outcome, but also the entire distribution of outcomes. This is possible because outcomes are estimated for each of the 771sample points used to represent cropped acres in the Chesapeake Bay region and for each of the 61 sample points used to represent land in long-term conserving cover. Cumulative distributions show the full set of estimates and thus demonstrate how conditions and the effects of conservation practices vary throughout the region.

Cumulative distributions shown in this report are plots of the value for each percentile. In figure 17, for example, the curve for average annual surface water runoff for the baseline conservation condition consists of each of the percentiles of the distribution of 771 surface water runoff estimates, weighted by the acres associated with each sample point. The $10^{th}$ percentile for the baseline conservation condition is 2.5 inches per year, indicating that 10 percent of the acres have 2.5 inches or less of surface water runoff, on average. Similarly, the same curve shows that 25 percent of the acres have surface water runoff less than 3.1 inches per year. The $50^{th}$ percentile—the median—is 4.2 inches per year, which in this case is close to the mean value of 4.5 inches per year. At the high end of the distribution, 90 percent of the acres in this region have surface water runoff less than 6.9 inches per year; and conversely, 10 percent of the acres have surface water runoff greater than 6.9 inches per year. The curves can also be used to define various ranges; for example, half of the cropped acres in the Chesapeake Bay region have average annual surface water runoff of 3.1-5.6 inches per year, where the range is based on the $25^{th}$ and $75^{th}$ percentiles.

Thus, the distributions show the full range of outcomes for cultivated cropland acres in the Chesapeake Bay region. The full range of outcomes for the baseline condition is compared to that for the no-practice scenario in figure 17 to illustrate the extent to which conservation practices reduce surface water runoff throughout the region.

Figure 19 shows the effects of conservation practices on surface water runoff using the distribution of the *reduction* in surface water runoff, calculated as the outcome for the no-practice scenario minus the outcome for the baseline conservation condition at each of the 771 cropped sample points. This distribution shows that, while the mean reduction is 0.9 inch per year, 17 percent of the acres have reductions due to conservation practices greater than 1.5 inches per year and 7 percent of the acres actually have small increases in surface water runoff (i.e., negative reductions) as a result of soil erosion control conservation practice use. (See footnote to figure 19 for an explanation of the conditions that result in gains in surface water runoff due to conservation practices.)

**Figure 20.** Estimates of average annual surface water runoff for land in long-term conserving cover in the Chesapeake Bay region

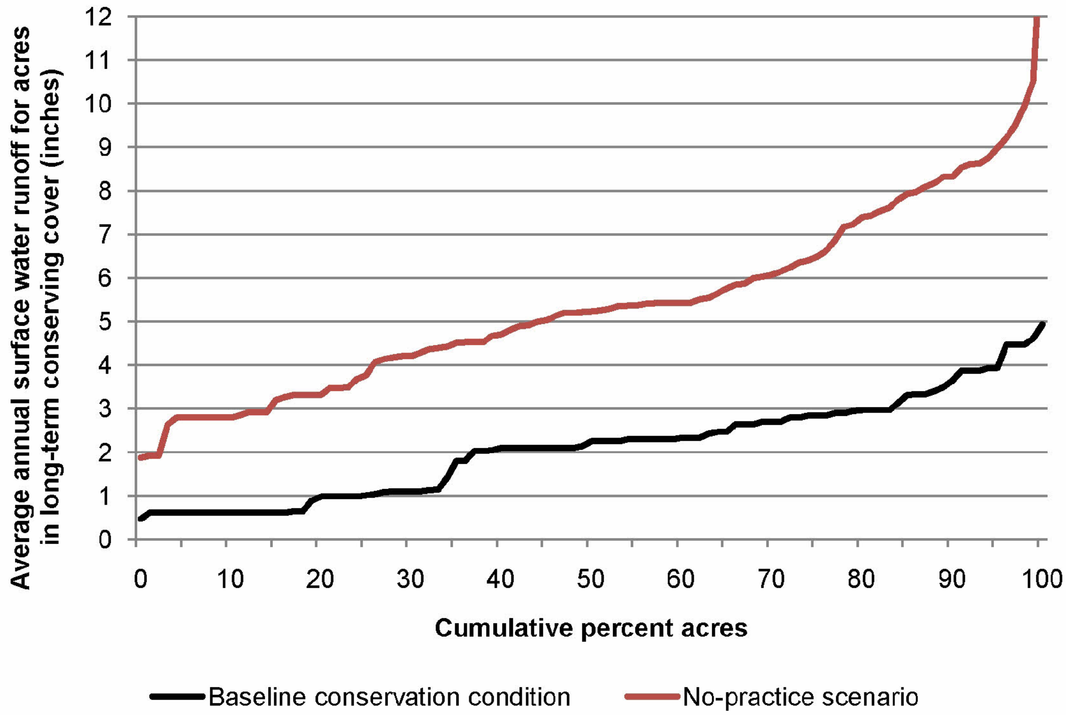
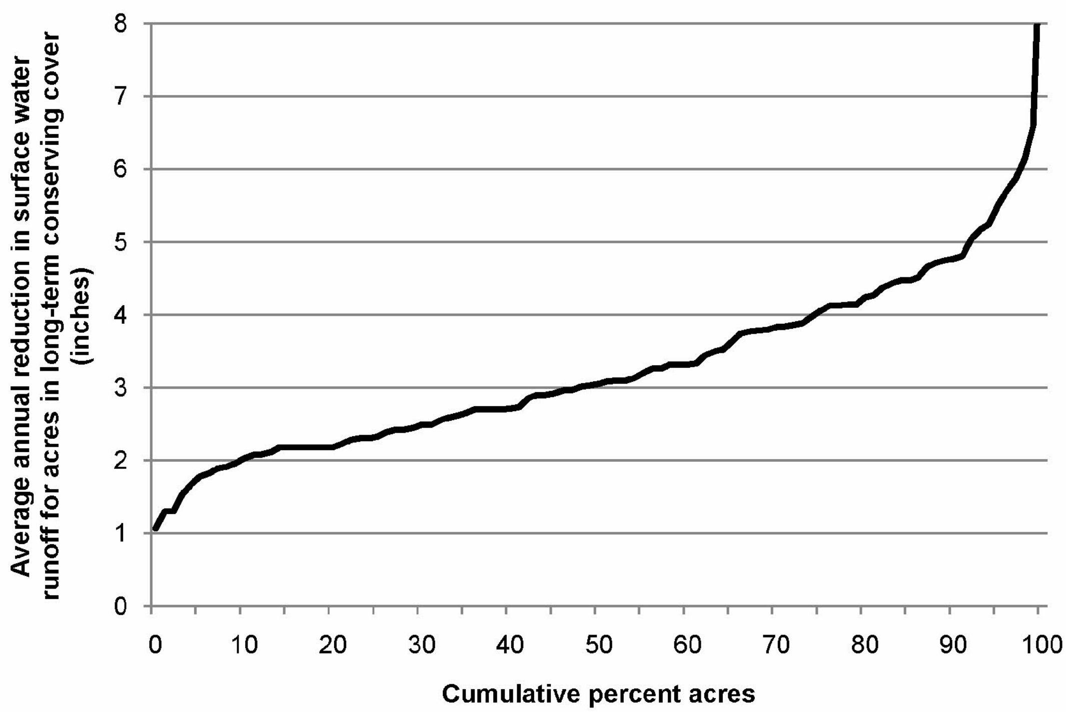



**Figure 21**. Estimates of average annual reduction in surface water runoff due to conversion to long-term conserving cover in the Chesapeake Bay region



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Residue and tillage management have about the same magnitude of effect on reducing surface water runoff as structural practices in this region, but combinations of the two practices are not additive (table 13). Acres with structural practices that also meet criteria for no-till or mulch till and are gaining soil organic carbon reduce surface water flow by an average of 19 percent.

Reductions for acres with structural practices that also meet criteria for no-till or mulch till but are losing soil organic carbon reduce surface water flow by slightly less, on average--17 percent. About 41 percent of the acres in the Chesapeake Bay region are in these two treatment categories (table 13). Slightly lower reductions occur for acres without structural practices.

**Table 13**. Estimates of effects of combinations of structural practices and residue and tillage management on average annual surface water runoff for cropped acres in the Chesapeake Bay region

| | | Average annual surface water runoff (inches) | | | |
|---|---|---|---|---|---|
| **Conservation treatment** | **Percent of cropped acres** | **Baseline conservation condition** | **No-practice scenario** | **Reduction due to practices** | **Percent reduction** |
| No-till or mulch till with carbon gain, no structural practices | 20 | 4.2 | 5.0 | 0.8 | 17 |
| No-till or mulch till with carbon loss, no structural practices | 27 | 4.6 | 5.5 | 0.9 | 16 |
| Some crops with reduced tillage, no structural practices | 2 | 4.6 | 5.2 | 0.6 | 11 |
| Structural practices and no-till or mulch till with carbon gain | 18 | 4.3 | 5.3 | 1.0 | 19 |
| Structural practices and no-till or mulch till with carbon loss | 23 | 4.7 | 5.7 | 1.0 | 18 |
| Structural practices and some crops with reduced tillage | 3 | 4.6 | 5.2 | 0.6 | 12 |
| Structural practices only | 3 | 4.9 | 5.6 | 0.8 | 14 |
| No water erosion control treatment | 4 | 4.8 | 5.1 | 0.3* | 6* |
| All acres | 100 | 4.5 | 5.4 | 0.9 | 17 |

* For non-irrigated sample points, the reduction due to practices for these acres with no water erosion control treatment was close to zero, as expected. For irrigated sample points, additional irrigation water was added to simulate lower water use efficiencies in the no-practice scenario, which explains the reduction in surface water runoff. In addition, surface water runoff was slightly affected by the higher nutrient application rates simulated in the no-practice scenario to estimate the benefits of nutrient management practices where they occurred.

Note: Differences in slope, soil texture, hydrologic group, and precipitation for acres in different treatment groups explain some of the differences shown in this table.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Note: Percents may not add to totals because of rounding.

## Erosion and Sediment Loss

### Wind erosion

Wind erosion removes the most fertile parts of the soil such as the lighter, less dense soil constituents including organic matter, clays, and silts. Wind erosion occurs when the soil is unprotected and wind velocity exceeds about 13 miles per hour near the surface. Wind velocity, tillage, vegetative cover, and the texture and structure of the soil are primary determinants of wind erosion. Wind erosion is estimated in APEX using the Wind Erosion Continuous Simulation (WECS) model. The estimated wind erosion rate is the amount of eroded material leaving the downwind edge of the field.

Wind erosion is a relatively minor resource concern in the Chesapeake Bay region. The greatest concern with wind erosion in the Chesapeake Bay region is crop damage to young seedlings exposed to windblown material. Wind erosion rates as low as 0.5 ton per acre are known to cause physical damage to young seedlings.

For all cropped acres, model simulations show that the average annual rate of wind erosion is only 0.03 ton per acre (table 14). Model simulations further show, however, that wind erosion can be an issue in some years for some acres (figure 22). In the most extreme year included in the model simulations (representing 1997), annual wind erosion exceeded 0.5 ton per acre for 4 percent of the cropped acres.

Structural practices for wind erosion control are in use on only 7 percent of the cropped acres in the Chesapeake Bay region. However, other practices common in the region, such as residue and tillage management, reduced tillage, and various water erosion control practices, are also effective in reducing wind erosion. Model simulations indicate that conservation practices have reduced the average wind erosion rate by 53 percent in the region (table 14). Even though wind erosion is not a major resource concern in the Chesapeake Bay region, these reductions in wind erosion rates are still significant.

**Table 14**. Field-level effects of conservation practices on erosion and sediment loss for cultivated cropland in the Chesapeake Bay region

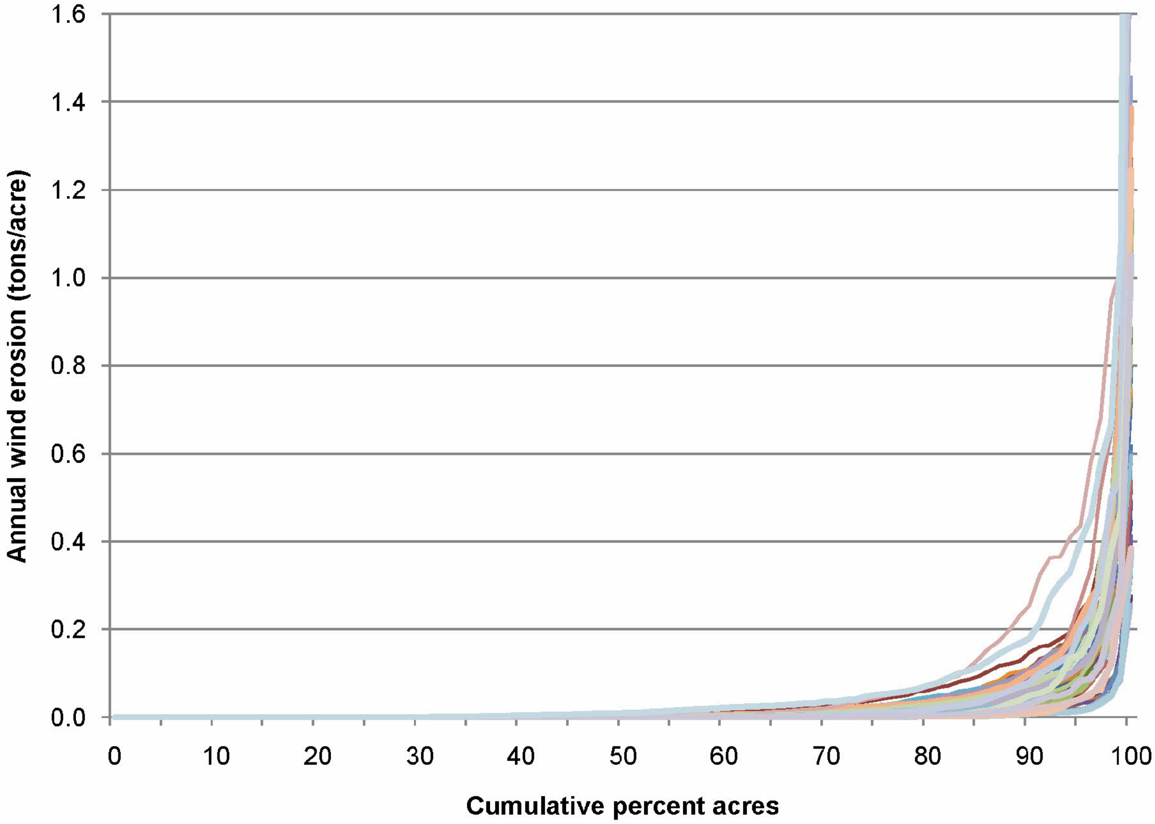
| Model simulated outcome | Baseline conservation condition | No-practice scenario | Reduction due to practices | Percent reduction |
|---|---|---|---|---|
| **Cropped acres (4.3 million acres)** | | | | |
| Average annual wind erosion (tons/acre) | 0.03 | 0.06 | 0.03 | 53 |
| Average annual sheet and rill erosion (tons/acre)* | 1.48 | 2.80 | 1.32 | 47 |
| Average annual sediment loss at edge of field due to water erosion (tons/acre) | 1.44 | 3.83 | 2.39 | 62 |
| **Highly erodible land (44 percent of cropped acres)** | | | | |
| Average annual wind erosion (tons/acre) | 0.01 | 0.04 | 0.02 | 63 |
| Average annual sheet and rill erosion (tons/acre)* | 2.45 | 4.63 | 2.19 | 47 |
| Average annual sediment loss at edge of field due to water erosion (tons/acre) | 2.50 | 6.76 | 4.26 | 63 |
| **Non-highly erodible land (56 percent of cropped acres)** | | | | |
| Average annual wind erosion (tons/acre) | 0.04 | 0.07 | 0.04 | 49 |
| Average annual sheet and rill erosion (tons/acre)* | 0.73 | 1.36 | 0.64 | 47 |
| Average annual sediment loss at edge of field due to water erosion (tons/acre) | 0.60 | 1.53 | 0.93 | 61 |
| **Land in long-term conserving cover (0.1 million acres)** | | | | |
| Average annual wind erosion (tons/acre) | 0.00 | 0.01 | 0.01 | 100 |
| Average annual sheet and rill erosion (tons/acre)* | 0.02 | 3.93 | 3.91 | 99 |
| Average annual sediment loss at edge of field due to water erosion (tons/acre) | 0.01 | 6.08 | 6.06 | 100 |

* Estimated using the Revised Universal Soil Loss Equation.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Note: Model simulation results for the baseline conservation condition are presented in appendix C for the 4 subbasins.

**Figure 22.** Distribution of annual wind erosion rate for each year of the 47-year model simulation, Chesapeake Bay region




**Note:** This figure shows how annual wind erosion (tons per acre per year) varied within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual wind erosion varied over the region in that year, starting with the acres with the lowest rates and increasing to the acres with the highest rates. The family of curves shows how annual wind erosion rates varied from year to year.

### Water erosion

Sheet and rill erosion is the detachment and movement of soil particles within the field that occurs during rainfall events. Controlling sheet and rill erosion is important for sustaining soil productivity and preventing soil from leaving the field.

Sediment loss, as referred to in this study, is the sediment that is transported beyond the edge of the field by water, where the field includes any edge-of-field filtering and buffering conservation practices. Soil erosion and sedimentation are separate but interrelated resource concerns. Soil erosion is the detachment and transport of soil particles, while sedimentation is that portion of the eroded material that settles out in areas onsite or offsite. Sediment loss, as estimated in this study, includes the portion of the sheet and rill eroded material that settles offsite as well as some sediment that originates from gully erosion processes.[20] Sediment is composed of detached and transported soil minerals, organic matter, plant and animal residues, and associated chemical and biological compounds.

The Chesapeake Bay has one of the highest proportions of cropland classified as highly erodible for water erosion of all the basins studied (44 percent). Most of these soils occur in the Piedmont, Appalachian, or Allegheny mountain or plateau physiographic regions. Soils in this region tend to occur on moderately sloping to steep landscapes. They are often relatively shallow agricultural soils with approximately half of the HEL lands classified with a soil loss tolerance (T) of 3 tons/acre/year.

**Sheet and rill erosion.** Model simulations show that sheet and rill erosion in the Chesapeake Bay region averages about 1.6 tons per acre per year (table 14). Sheet and rill erosion rates are higher for highly erodible land, averaging 2.4 tons per acre per year compared to the average annual rate for non-highly erodible land of 0.7 ton per acre.

Model simulation results also show that conservation practices have reduced sheet and rill erosion on cropped acres in the Chesapeake Bay region by an average of 1.32 tons per acre per year, representing a 47-percent reduction on average (table 14). While the average annual reduction in sheet and rill

[20] For this study, the APEX model was set up to estimate sediment loss using a modified version of USLE, called MUSS, which uses an internal sediment delivery ratio to estimate the amount of eroded soil that actually leaves the boundaries of the field. A large percentage of the eroded material is redistributed and deposited within the field or trapped by buffers and other conservation practices and does not leave the boundary of the field, which is taken into account in the sediment delivery calculation. The estimate also includes some gully erosion and some ephemeral gully erosion. For this reason, sediment loss rates can exceed sheet and rill erosion rates.

erosion for highly erodible land is more than 3 times that for non-highly erodible acres (table 14), the percent reduction due to conservation practices is about the same.

For land in long-term conserving cover, sheet and rill erosion has been reduced from 3.9 tons per acre per year if cropped without conservation practices to less than 0.1 ton per acre (table 14), on average.

**Sediment loss due to water erosion.** The average annual sediment loss for cropped acres in the Chesapeake Bay region is 1.4 tons per acre per year, according to the model simulation (table 14). As seen for sheet and rill erosion, sediment loss for highly erodible land is much higher than for non-highly erodible land.On an annual basis, sediment loss can vary considerably. Figure 23 shows that, with the conservation practices currently in use in the Chesapeake Bay region, annual sediment loss is below 2 tons per acre for about 60 percent of the acres under all conditions, including years with high precipitation. In contrast, sediment loss exceeds 12 tons per acre in one or more years on about 15 percent of the cropped acres.

Model simulations indicate that the use of conservation practices in the Chesapeake Bay region has reduced average annual sediment loss due to water erosion by 62 percent for cropped acres in the region, including both treated and untreated acres (table 14). Without conservation practices, the average annual sediment loss for these acres would have been 3.8 tons per acre per year—over twice as much as the 1.4 tons per acre average for the baseline conservation condition. Figure 24 shows that about 51 percent of the acres would have less than 2 tons per acre per year sediment loss without practices, on average, compared to 77 percent with conservation practices.

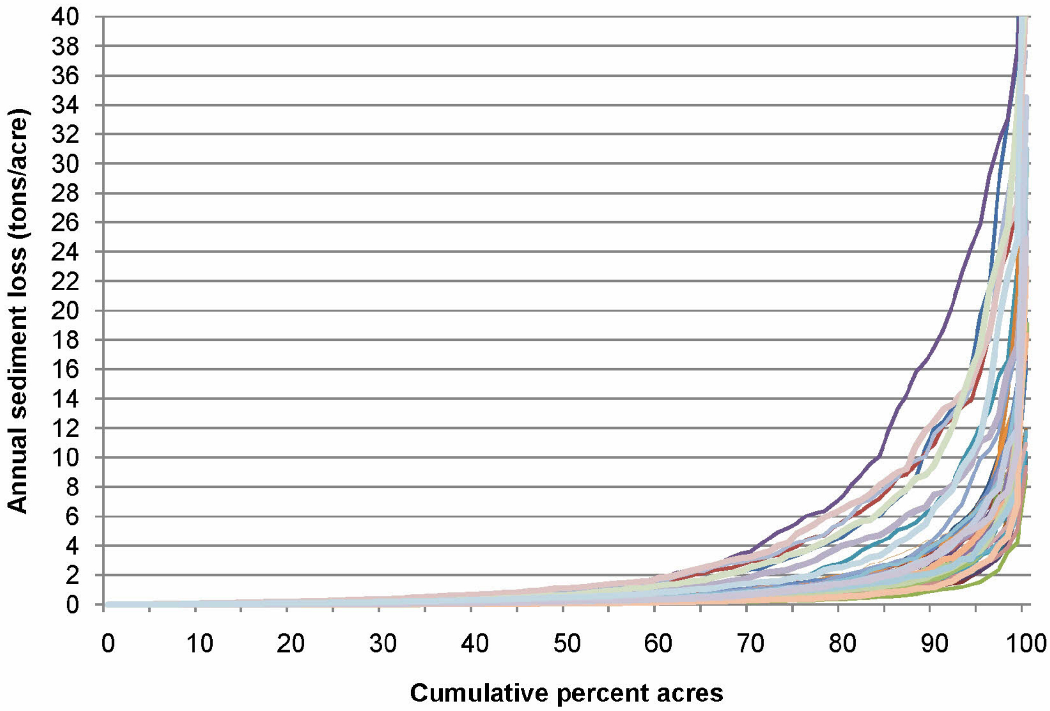
Reductions in sediment loss due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil. For about half of the acres, the average annual sediment loss reduction due to practices is less than 1 ton per acre (figure 25). The top 10 percent of the acres had reductions in average annual sediment loss greater than 5.7 tons/acre.

Acres with a combination of structural practices and residue and tillage management have the highest percent reduction in sediment loss (table 15). Acres that are treated with structural practices, meet tillage intensity criteria for no-till or mulch till, and are gaining soil organic carbon (about 18 percent of cropped acres) have reduced sediment loss by 85 percent, on average. For these treated acres, annual sediment loss averages only about 0.6 ton per acre.

Acres in long-term conserving cover have very little erosion or sediment loss, and thus show nearly 100 percent reductions when compared to a cropped condition (table 14, figure 26). If these acres were still being cropped without any conservation practices, sediment loss would average about 6 tons per acre per year on these 100,000 acres.

Reductions in sediment loss for land in long-term conserving cover compared to the same acres with crops and no conservation practices vary considerably, as shown in figure 27. While the average reduction over all acres in long-term conserving cover is 6 tons per acre per year, one-third of the acres in long-term conserving cover have reductions of less than 2 tons per acre per year average. Reductions greater than 10 tons per acre per year occur on about 20 percent of the acres.

**Figure 23**. Distribution of annual sediment loss for each year of the 47-year model simulation, Chesapeake Bay region




**Note:** This figure shows how annual sediment loss (tons per acre per year) varied within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual sediment loss varied over the region in that year, starting with the acres with the lowest sediment loss and increasing to the acres with the highest sediment loss. The family of curves shows how annual sediment loss varied from year to year.

**Table 15**. Estimates of effects of combinations of structural practices and residue and tillage management on average annual sediment loss for cropped acres in the Chesapeake Bay region

| | | Average annual sediment loss (tons/acre) | | | |
|---|---|---|---|---|---|
| **Conservation treatment** | **Percent of cropped acres** | **Baseline conservation condition** | **No-practice scenario** | **Reduction due to practices** | **Percent reduction** |
| No-till or Mulch till with carbon gain, no structural practices | 20 | 0.43 | 1.16 | 0.73 | 63 |
| No-till or mulch till with carbon loss, no structural practices | 27 | 1.46 | 2.47 | 1.01 | 41 |
| Some crops with reduced tillage, no structural practices | 2 | 1.81 | 2.46 | 0.65 | 26 |
| Structural practices and No-till or Mulch till with carbon gain | 18 | 0.63 | 4.04 | 3.41 | 85 |
| Structural practices and No-till or Mulch till with carbon loss | 23 | 2.61 | 7.61 | 4.99 | 66 |
| Structural practices and some crops with reduced tillage | 3 | 1.00 | 4.30 | 3.29 | 77 |
| Structural practices only | 3 | 2.71 | 5.84 | 3.13 | 54 |
| No water erosion control treatment | 4 | 2.76 | 2.88 | 0.12* | 4* |
| All acres | 100 | 1.44 | 3.83 | 2.39 | 62 |

* For non-irrigated sample points, the reduction due to practices for these acres with no water erosion control treatment was close to zero, as expected. For irrigated sample points, additional irrigation water was added to simulate lower water use efficiencies in the no-practice scenario, which contributes to higher sediment loss in the no-practice scenario. In addition, sediment loss was slightly affected by the higher nutrient application rates simulated in the no-practice scenario to estimate the benefits of nutrient management practices where they occurred.

Note: Differences in slope, soil texture, hydrologic group, and precipitation for acres in different treatment groups account for some of the differences shown in this table. Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.

**Figure 24**. Estimates of average annual sediment loss for cropped acres in the Chesapeake Bay region

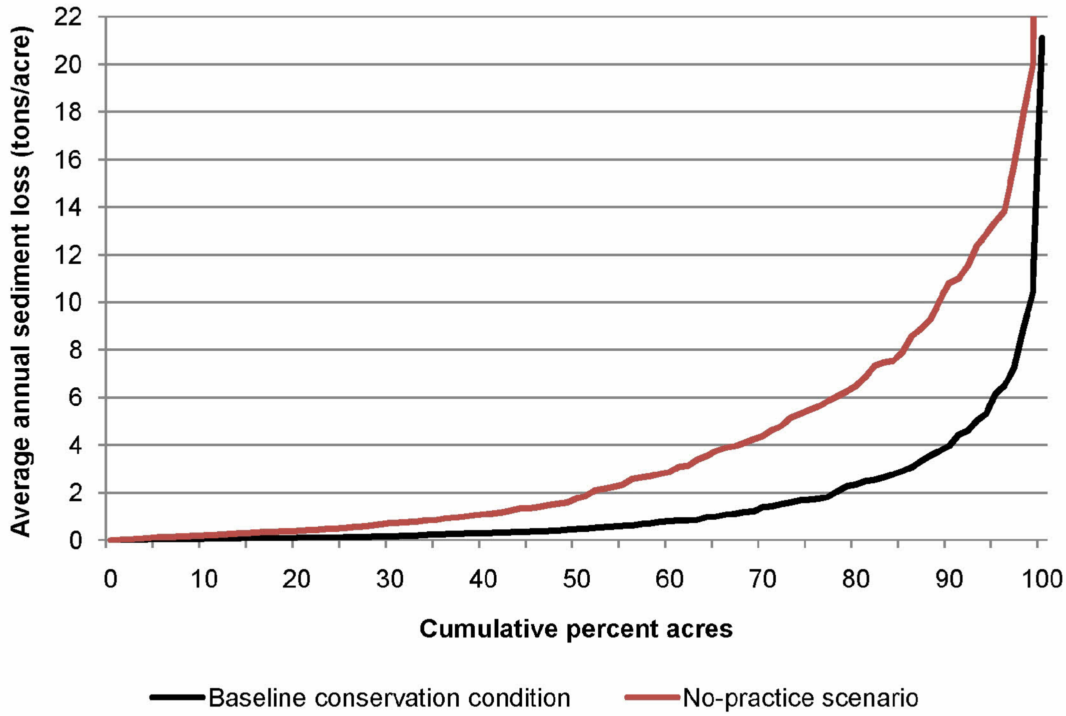
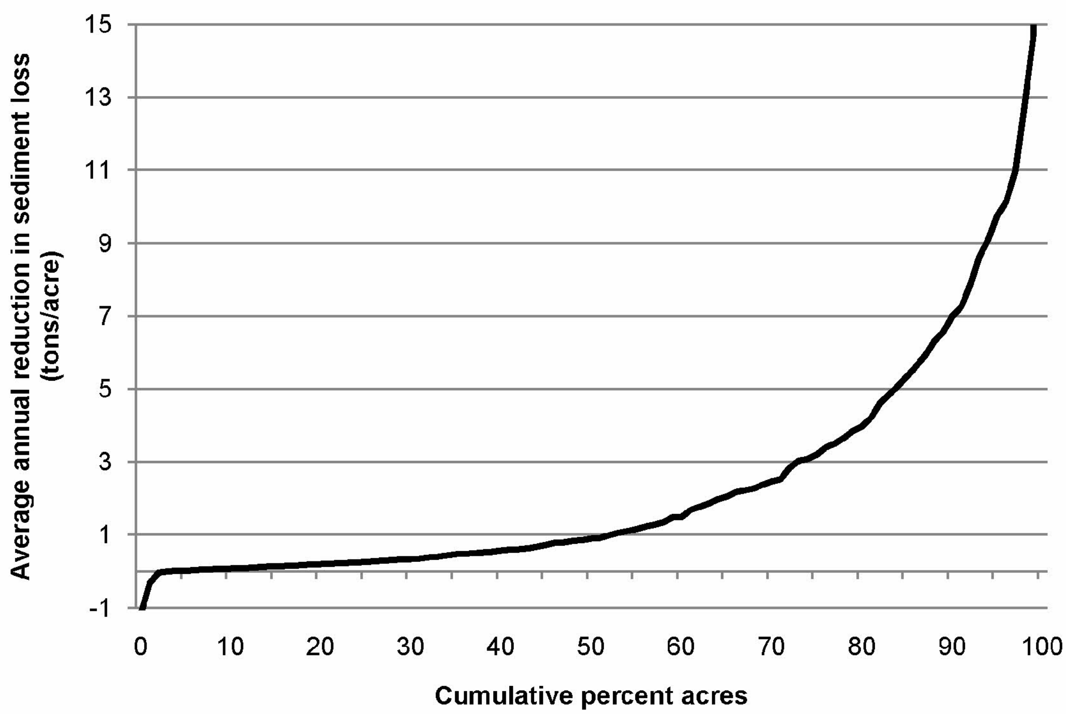



**Figure 25**. Estimates of average annual reduction in sediment loss due to the use of conservation practices on cropped acres in the Chesapeake Bay region




Note: About 2 percent of the acres had less sediment loss in the no-practice scenario than the baseline conservation condition, resulting from the increase is surface water runoff on some acres due to conservation practices. See footnote to figure 19.

**Figure 26**. Estimates of average annual sediment loss for acres in long-term conserving cover in the Chesapeake Bay region

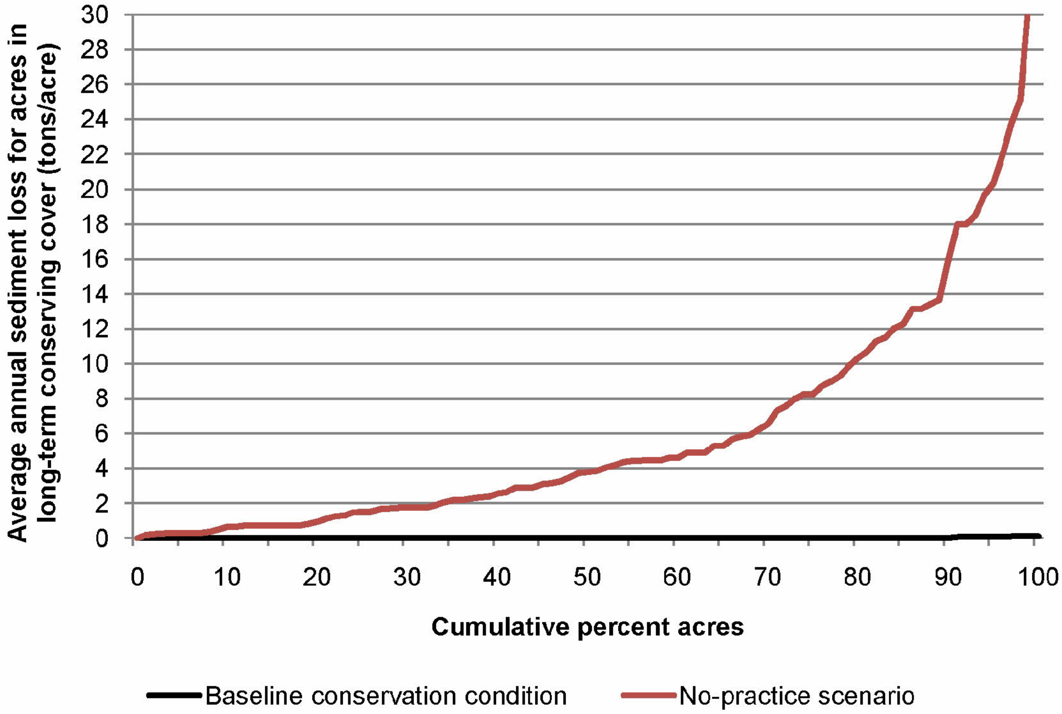
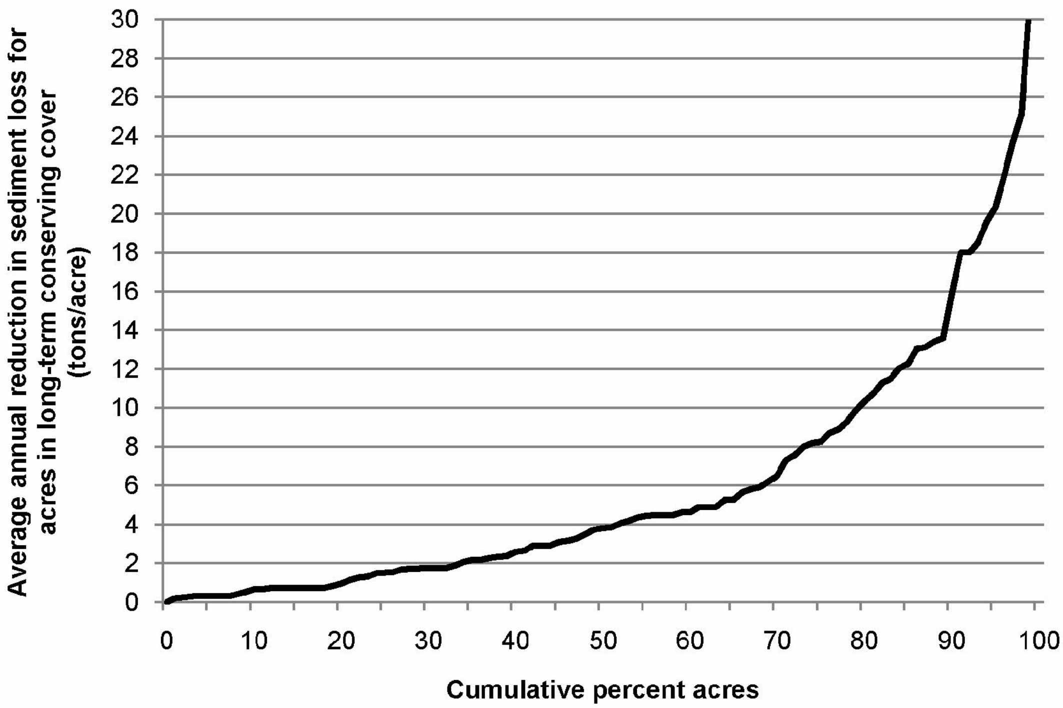



**Figure 27**. Estimates of average annual reduction in sediment loss due to conversion to long-term conserving cover in the Chesapeake Bay region



## Soil Organic Carbon

The landscape and climate in the Chesapeake Bay region is much less conducive to maintaining and enhancing soil organic carbon relative to landscapes and climate of the soils in the Midwest. The combination of higher rainfall on more sloping soils and milder winters that allow for more degradation of organic materials make carbon accumulation far more challenging. The soils in this region developed residuum from igneous and metamorphic bedrock, glacial outwash or sandy coastal plain sediments. These materials are highly weathered with mixed or siliceous mineralogies, causing them to be inherently less fertile. The highly weathered, less reactive nature of these soils makes them less able to withstand even moderately intense tillage and maintain or enhance carbon stores relative to regions of the country like the Mississippi River drainage basin.

The estimation of soil organic carbon change is based on beginning soil characteristics that reflect the effects of years of traditional conventional tillage practices and older, lower yielding crop varieties. These effects generally resulted in soils with organic carbon levels at or near their low steady state. Modern high yielding crop varieties with and without the adoption of conservation tillage tend to readily improve the status of carbon in many soils, especially those with beginning stocks far less than the steady state representation of the present management. Beginning the simulations at a lower steady state for carbon allows for a more equitable comparison of conservation practices, particularly conservation tillage. Because of this, however, model estimates of soil organic carbon change may be somewhat larger than shown in other studies. Nevertheless, model estimates obtained in this study fall within the expected range for the continuum of adoption of new crop genetics and tillage practices.

Model simulation shows that for the baseline conservation condition the average annual carbon change is a loss of about 37 pounds per acre per year, on average (table 16). Without conservation practices, the annual change in soil organic carbon would be an average loss of 92 pounds per acre per year. Thus, conservation practices in the region have resulted in an average annual increase in soil organic carbon of 55 pounds per acre per year on cropped acres.

However, average annual change in soil organic carbon varies considerably among acres in the region, as shown in figure 28. For the baseline conservation condition, about 40 percent of the acres are gaining soil organic carbon (figure 28); for these acres, the annual average gain in soil organic carbon is 76 pounds per acre per year. If conservation practices were not in use, only 28 percent of the acres would be gaining soil organic carbon and the annual rate of gain would be only 58 pounds per acre per year on those acres.

Cropped acres that are gaining soil organic carbon every year provide soil quality benefits that enhance production and reduce the potential for sediment, nutrient, and pesticide losses. Soil organic carbon improves the soil's ability to function with respect to nutrient cycling, improves water holding capacity, and reduces erodibility. However, enhancement of carbon stores on a scale seen in the Midwestern basins could only occur in this region with significant shifts in crop mixes toward rotations with hay or pasture as components. Given the challenging nature of the inherent conditions of this region, maintenance of soil organic carbon is also an important benchmark. Cropping systems can be considered to be maintaining soil organic carbon if average annual losses do not exceed 100 pounds per acre per year; this rate of change is typically too small to detect via typical soil sampling over a 20-year period. Applying this criterion, about 36 percent of the acres in the region would be considered to be maintaining (but not enhancing) soil organic carbon. When combined with acres enhancing soil organic carbon (gaining soil organic carbon), a total of 76 percent of the acres in the region would be either maintaining or enhancing soil organic carbon. This achievement is in large part due to the high rate of conservation tillage adoption, particularly no-till and the high residue crop rotations on most of the acres.

For land in long-term conserving cover, the gain in soil organic carbon for the baseline conservation condition averages 199 pounds per acre per year. If these acres were still being cropped without any conservation practices, the annual average change in soil organic carbon would be a loss of 134 pounds per acre per year.

These estimates account for losses of carbon with sediment removed from the field by wind and water erosion. Some of the increased gain in soil organic carbon due to conservation practices is the result of soil erosion control—keeping soil organic carbon on the field promotes soil quality. Loss of soil organic carbon due to wind and water erosion averages about 162 pounds per acre per year for the baseline conservation condition (table 16). If conservation practices were not in use, loss of soil organic carbon due to wind and water erosion would average 205 pounds per acre per year.

For air quality concerns, the analysis centers on the decrease in $CO_2$ emissions. Soils gaining carbon are obviously diminishing emissions, but so are soils that continue to lose carbon but at a slower rate. For all cropped acres, the reduction in carbon emissions for farm fields averages 55 pounds per acre due to conservation practice use, equivalent to a $CO_2$ emission reduction of 0.43 million U.S. tons of carbon dioxide. For acres in long-term conserving cover (only 100,00 acres in the region), the reduction in carbon emissions averages 333 pounds per acre compared to a cropped condition without conservation practices, equivalent to a $CO_2$ emission reduction of 0.06 million U.S. tons of carbon dioxide. However, the rate of emission reduction due to conservation practices varies considerably among acres, as shown in figures 29 and 30.

As observed for sediment loss, acres with a combination of structural practices and residue and tillage management have the highest annual increases in soil organic carbon, and thus the highest decrease in CO2 emissions (table 17). This is primarily due to reductions in erosion losses for treated acres.

**Table 16**. Field-level effects of conservation practices on soil organic carbon for cultivated cropland in the Chesapeake Bay region

| Model simulated outcome | Baseline conservation condition | No-practice scenario | Reduction due to practices | Percent reduction |
|---|---|---|---|---|
| **Cropped acres (4.3 million acres)** | | | | |
| Average annual loss of carbon with wind and water erosion (pounds/acre) | 162 | 205 | 42 | 21 |
| Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre) | -37 | -92 | 55* | -- |
| **Land in long-term conserving cover (0.1 million acres)** | | | | |
| Average annual loss of carbon with wind and water erosion (pounds/acre) | 40 | 291 | 251 | 86 |
| Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre) | 199 | -134 | 333* | -- |

* Gain in soil organic carbon due to conservation practices.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix C for the 4 subbasins.

**Table 17**. Estimates of effects of combinations of structural practices and residue and tillage management on average annual soil organic carbon change for cropped acres in the Chesapeake Bay region

| | | Average annual change in soil organic carbon (pounds/acre) | | |
|---|---|---|---|---|
| **Conservation treatment** | **Percent of cropped acres** | **Baseline conservation condition** | **No-practice scenario** | **Gain due to practice (pounds/acre)** |
| No-till or Mulch till with carbon gain, no structural practices | 20 | 69 | 32 | 37 |
| No-till or mulch till with carbon loss, no structural practices | 27 | -96 | -122 | 26 |
| Some crops with reduced tillage, no structural practices | 2 | -136 | -154 | 18 |
| Structural practices and No-till or Mulch till with carbon gain | 18 | 83 | 2 | 81 |
| Structural practices and No-till or Mulch till with carbon loss | 23 | -119 | -212 | 93 |
| Structural practices and some crops with reduced tillage | 3 | -54 | -128 | 74 |
| Structural practices only | 3 | -78 | -152 | 74 |
| No water erosion control treatment | 4 | -121 | -124* | 3* |
| All acres | 100 | -37 | -92 | 55 |

* The slight gain in soil organic carbon due to practices for these acres with no water erosion control treatment is due to:1) additional irrigation water that was added to simulate lower water use efficiencies in the no-practice scenario, and 2) higher nutrient application rates simulated in the no-practice scenario to estimate the benefits of nutrient management practices where they occurred.
Note: Estimates include reductions in loss of carbon from the field through wind and water erosion that are due to the use of conservation practices. Differences in slope, soil texture, hydrologic group, and precipitation for acres in different treatment groups explain some of the differences in sediment loss shown in this table.
Note: Percents may not add to totals because of rounding.

**Figure 28**. Estimates of average annual change in soil organic carbon for cropped acres in the Chesapeake Bay region

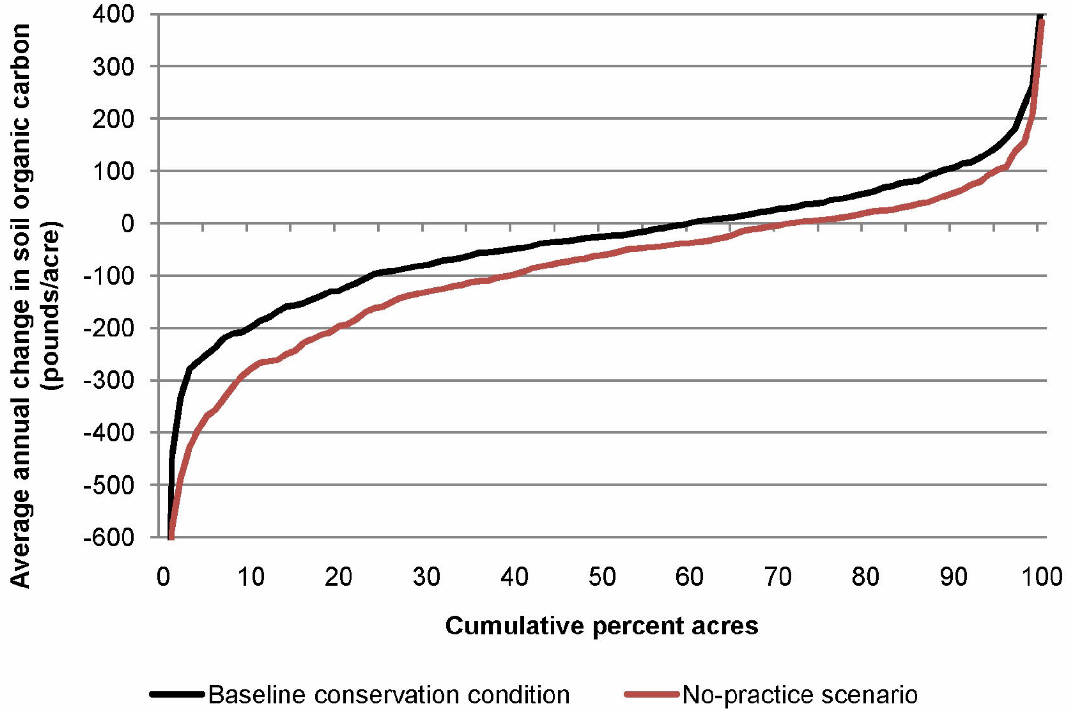
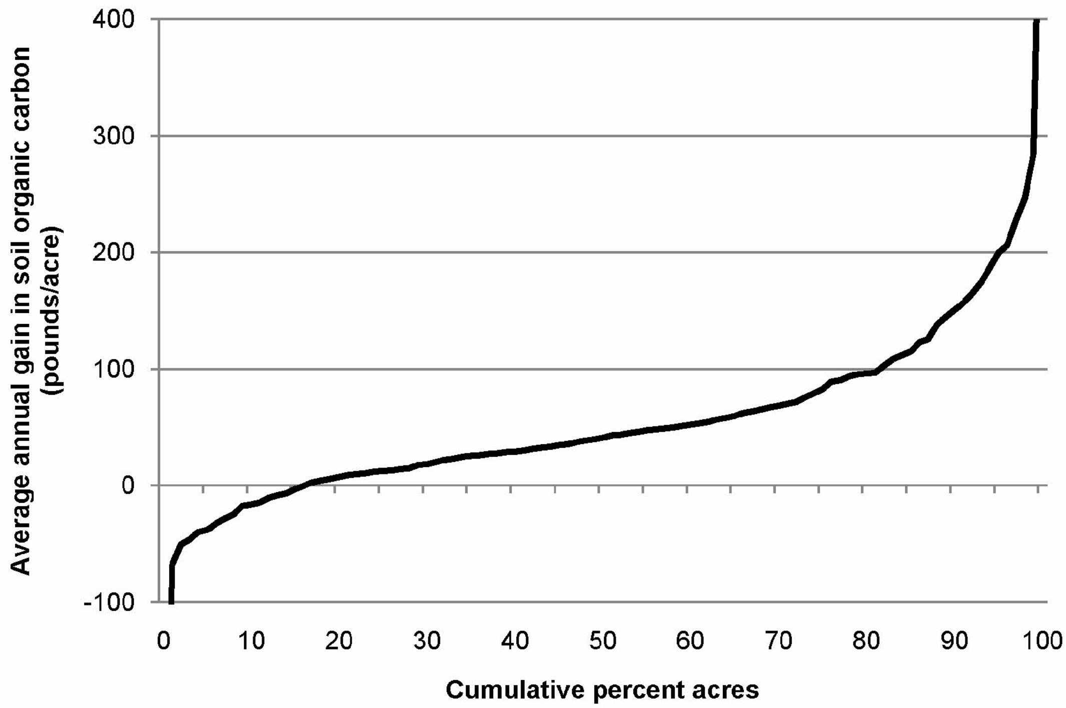
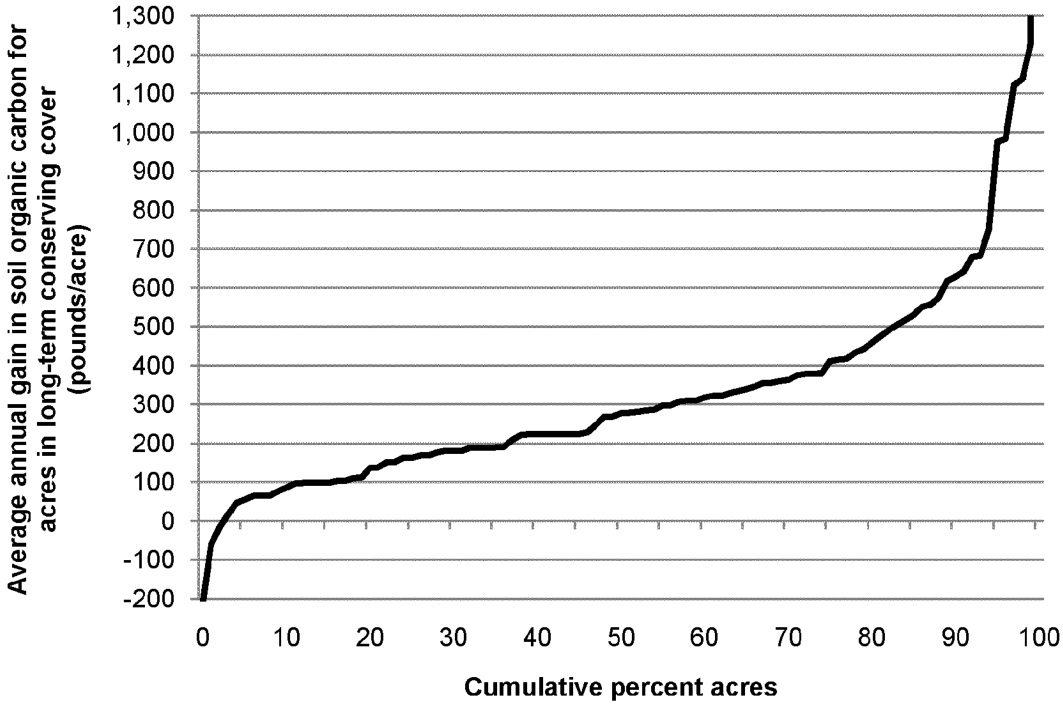



**Figure 29.** Estimates of average annual gain in soil organic carbon due to the use of conservation practices on cropped acres in the Chesapeake Bay region




Note: About 16 percent of the acres have a higher soil organic carbon increase in the no-practice scenario than the baseline conservation condition because of the higher fertilization rates, including manure application rates, used in the no-practice scenario to simulate the effects of nutrient management practices. Reductions in manure application reduce the rate of build-up of soil organic carbon. Reductions in commercial fertilizer application can also reduce the amount of residue produced when other conservation practices are inadequate to control losses.

**Figure 30.** Estimates of average annual gain in soil organic carbon due to conversion to long-term conserving cover in the Chesapeake Bay region




Note: About 2 percent of the acres in long-term conserving cover have decreases in annual carbon gain compared to a cropped condition. Biomass production under long-term conserving cover is typically nitrogen limited. The higher biomass production and resulting crop residue from the fertilization of cropped acres can exceed the carbon benefits of long-term conserving cover under some conditions.

## Nitrogen Loss

Plant-available nitrogen sources include application of commercial fertilizer, application of manure, nitrogen produced by legume crops (soybeans, alfalfa, beans, and peas), a small amount of manure deposited by grazing livestock, and atmospheric nitrogen deposition. In total, these sources provide about 131 pounds of nitrogen per acre per year for cropped acres in the Chesapeake Bay region (table 18). Model simulations show that about 64 percent of this (83 pounds per acre) is taken up by the crop and removed at harvest in the crop yield, on average, and the remainder is lost from the field through various pathways.

For the baseline conservation condition, the annual average amount of total nitrogen lost from the field, other than the nitrogen removed from the field at harvest, is about 53 pounds per acre. These nitrogen loss pathways are—

- nitrogen lost due to volatilization associated with fertilizer and manure application (average of 6.9 pounds per acre per year);
- nitrogen returned to the atmosphere through denitrification processes (average of 1.6 pounds per acre per year);
- nitrogen lost with windborne sediment (average of 0.1 pounds per acre per year);
- nitrogen lost with surface runoff, including nitrogen lost with waterborne sediment (average of 9.7 pounds per acre per year); and
- nitrogen loss in subsurface flow pathways (average of 34.2 pounds per acre per year).

In the model simulations for the Chesapeake Bay region, about 77 percent of the nitrogen loss in subsurface flows from fields eventually returns to surface water, on average, while about 23 percent is carried with water flow that recharges the underlying aquifers.

Most nitrogen is lost in subsurface flows, as shown in figure 31. The percent of nitrogen lost in each loss pathway varies from acre to acre, as shown in figure 32. The dominant nitrogen loss pathway for most cropped acres (78 percent) in the Chesapeake Bay region is nitrogen loss in subsurface flows. On average for all acres in the region, 65 percent of the nitrogen lost from fields is through subsurface flows. Nitrogen volatilization or nitrogen lost as waterborne sediment are the next highest loss pathways, averaging 13 percent and 27 percent of total nitrogen loss, respectively. Nitrogen loss with waterborne sediment is the dominant loss pathway for 16 percent of the acres, while volatilization is the dominant loss pathway for 5 percent of the acres. Nitrogen loss in surface water runoff (soluble), windborne sediment, and nitrogen lost through denitrification are rarely the dominant loss pathways in this region.

In both the baseline conservation condition and the no-practice scenario, average annual nitrogen losses for all loss pathways except harvest were much higher for acres receiving manure than for acres that did not receive manure (table 18). Losses were also higher for highly erodible land than for non-highly erodible land.

### Total nitrogen loss

Model simulations for the baseline conservation condition indicate that some cropped acres in the Chesapeake Bay region are much more susceptible to the effects of weather than other acres and lose much higher amounts of nitrogen (figure 33). About 25 percent of the acres lose less than 40 pounds per acre per year through the various loss pathways other than removal at harvest under *all* weather conditions. About 20 percent of the acres, on the other hand, lose more than 140 pounds per acre in at least some years. Figure 33 also shows that nitrogen loss for the 20 percent of the cropped acres with the highest losses varies dramatically from year to year when compared to the 40 percent with the lowest total nitrogen loss. Figure 33 further shows that, in the Chesapeake Bay region, total nitrogen loss from cropped acres can exceed 40 pounds per acre in every year on about 20 percent of the acres.

Model simulations show that the conservation practices in use in the region have reduced total nitrogen loss from cropped acres (exclusive of nitrogen removed at harvest with the crop yield) by an average of 22 pounds per acre per year, representing a 30 percent reduction, on average (table 18). Without conservation practices, about 68 percent of the cropped acres would have average annual total nitrogen loss exceeding 40 pounds per acre per year; with conservation practices, 45 percent of acres exceed this level of loss (figure 34).

The effects of conservation practices vary from acre to acre (figure 35). About half of the acres have average annual reductions in total nitrogen loss below 14 pounds per acre. In contrast, about 18 percent of the acres have reduced total nitrogen loss by an average of over 40 pounds per acre per year (figure 35). These are acres with higher levels of treatment, including acres with higher levels of nitrogen use and thus more nitrogen available to be reduced by practices. For example, the acres with manure applied had total nitrogen reductions averaging 31 pounds per acre per year, twice the average reduction for acres that did not receive manure (table 18). Similarly, the average reduction in total nitrogen loss on highly erodible land is higher than for non-highly erodible land (table 18).

Figure 35 also shows that about 12 percent of the acres have an increase in total nitrogen loss due to conservation practice use. Most of these gains are small; only 2 percent of the acres have gains of more than 5 pounds per acre. This result primarily occurs on soils with relatively high soil nitrogen content and generally with low slopes where the surface water runoff is re-directed to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices. Cropping systems that include legumes also have a higher soil nitrogen stock in the baseline conditions because legumes produce proportionately less biofixation of nitrogen under the higher fertilization rates simulated in the no-practice scenario.

The baseline conservation condition represents a wide range of conservation adoption. Adoption of soil erosion control practices without also adopting sound nutrient management can have a negative impact on nitrogen loss.

Total nitrogen loss has been reduced by about 89 percent on the 0.1 million acres in long-term conserving cover, compared to the conditions that would be expected had the acres remained in crops. Converting cropped acres to long-term conserving cover is very effective in reducing total nitrogen loss, as demonstrated in figures 36 and 37 and table 18, although the reductions are much higher for some acres than others. Sixty percent of the acres in long-term conserving cover have reductions of more than 40 pounds of nitrogen loss per acre per year, compared to a cropped condition.

### Nitrogen lost with surface runoff

Model simulations show that, on average, nitrogen lost with surface runoff has been reduced 42 percent due to use of conservation practices in the region (table 18). Without conservation practices, about 38 percent of the cropped acres would have nitrogen lost with surface runoff in excess of an average of 15 pounds per acre per year, compared to only 20 percent of the acres in the baseline conservation condition (figure 38). Figure 39 shows that some acres have large reductions in nitrogen lost with surface runoff due to conservation practice use. Figure 39 also shows that about 45 percent of the acres have reductions less than 3 pounds per acre due to conservation practices.

### Nitrogen loss in subsurface flows

Conservation practices had less effect on nitrogen loss in subsurface flows in the Chesapeake Bay region, as shown in figure 40. Without conservation practices, about 63 percent of the cropped acres would have nitrogen lost with surface runoff in excess of an average of 25 pounds per acre per year, compared to only 38 percent of the acres in the baseline conservation condition. On average, nitrogen loss in subsurface flows has been reduced 32 percent due to use of conservation practices in the region (table 18). Figure 39 shows that reductions in nitrogen loss in subsurface flows exceed 40 pounds per acre for 10 percent of the cropped acres, on average, due to conservation practice use. Figure 39 also shows, however, that reductions of 3 pounds or less occur for about one-third of the acres.

On 15 percent of the cropped acres, nitrogen loss in subsurface flows *increased* as a result of conservation practices. (Gains in nitrogen loss in subsurface flows are represented in figure 39 as negative reductions.) This is largely due to relatively weak nutrient management practices on acres with erosion control treatment. A portion of the reduction in nitrogen lost with surface runoff is re-routed to subsurface loss pathways, resulting in gains or only small reductions in nitrogen loss in subsurface flows. This re-routing of surface water runoff to subsurface flow pathways results in additional nitrogen being leached from the soil, diminishing and sometimes offsetting the overall positive effects of conservation practices on total nitrogen loss. These model simulation results underscore the importance of pairing water erosion control practices with effective nutrient management practices so that the full suite of conservation practices will provide the environmental protection needed.

**Table 18**. Field-level effects of conservation practices on nitrogen sources and nitrogen loss pathways for cropped acres in the Chesapeake Bay region

| | Average annual values in pounds per acre | | | |
|---|---|---|---|---|
| **Model simulated outcome** | **Baseline conservation condition** | **No-practice scenario** | **Reduction due to practices** | **Percent reduction** |
| **Cropped acres (4.3 million acres)** | | | | |
| **Nitrogen sources** | | | | |
| Atmospheric deposition | 8.7 | 8.7 | 0.0 | 0 |
| Bio-fixation by legumes | 26.3 | 23.5 | -2.8 | -12 |
| Nitrogen applied as commercial fertilizer and manure | 95.6 | 124.7 | 29.1 | 23 |
| All nitrogen sources | 130.7 | 156.9 | 26.3 | 17 |
| **Nitrogen loss pathways** | | | | |
| Nitrogen in crop yield removed at harvest | 83.1 | 92.2 | 9.1 | 10 |
| Nitrogen loss by volatilization | 6.9 | 6.2 | -0.7** | -11** |
| Nitrogen loss through denitrification processes | 1.6 | 1.2 | -0.4** | -35** |
| Nitrogen lost with windborne sediment | 0.1 | 0.2 | 0.1 | 42 |
| Nitrogen loss with surface runoff, including waterborne sediment | 9.7 | 16.7 | 7.0 | 42 |
| Nitrogen loss with surface water (soluble) | 0.7 | 1.7 | 0.9 | 56 |
| Nitrogen loss with waterborne sediment | 9.0 | 15.1 | 6.1 | 40 |
| Nitrogen loss in subsurface flow pathways | 34.2 | 50.4 | 16.2 | 32 |
| Nitrogen lost to surface runoff (surface and subsurface flow pathways excluding nitrogen loss in water recharging aquifers) | 36.1 | 55.3 | 19.2 | 35 |
| Total nitrogen loss for all pathways except harvest | 52.6 | 74.9 | 22.2 | 30 |
| **Change in soil nitrogen** | -6.3 | -11.2 | -4.9 | -- |
| **Highly erodible land (44percent of cropped acres)** | | | | |
| All nitrogen sources | 133.4 | 158.9 | 25.5 | 16 |
| Total nitrogen loss for all pathways except harvest | 63.8 | 90.3 | 26.5 | 29 |
| **Non-highly erodible land (56 percent of cropped acres)** | | | | |
| All nitrogen sources | 128.5 | 155.4 | 26.9 | 17 |
| Total nitrogen loss for all pathways except harvest | 43.9 | 62.8 | 18.9 | 30 |
| **Acres with manure applied (38 percent of cropped acres)** | | | | |
| All nitrogen sources | 160.4 | 194.0 | 33.7 | 17 |
| Total nitrogen loss for all pathways except harvest | 77.7 | 108.7 | 31.0 | 29 |
| **Acres without manure applied (62 percent of cropped acres)** | | | | |
| All nitrogen sources | 112.6 | 134.4 | 21.8 | 16 |
| Total nitrogen loss for all pathways except harvest | 37.4 | 54.3 | 16.9 | 31 |
| **Land in long-term conserving cover (0.1 million acres)** | | | | |
| **Nitrogen sources** | | | | |
| Atmospheric deposition | 8.7 | 8.7 | 0.0 | 0 |
| Bio-fixation by legumes | 11.8 | 21.9 | 10.1 | 46 |
| Nitrogen applied as commercial fertilizer and manure | 0.0 | 133.3 | 133.3 | 100 |
| All nitrogen sources | 20.5 | 163.9 | 143.4 | 88 |
| **Nitrogen loss pathways** | | | | |
| Nitrogen in crop yield removed at harvest | 1.3*** | 81.9 | 80.6 | 98 |
| Nitrogen loss by volatilization | 4.7 | 6.2 | 1.4 | 23 |
| Nitrogen loss through denitrification processes | 1.9 | 3.0 | 1.1 | 37 |
| Nitrogen lost with windborne sediment | <0.1 | <0.1 | <0.1 | 100 |
| Nitrogen loss with surface runoff , including waterborne sediment | 0.3 | 24.4 | 24.1 | 99 |
| Nitrogen loss in subsurface flow pathways | 2.8 | 59.7 | 57.0 | 95 |
| Total nitrogen loss for all pathways except harvest | 9.7 | 93.3 | 83.7 | 90 |
| **Change in soil nitrogen** | 5.8 | -15.4 | -21.2 | -- |

* The reduction in yield reflects the increase in nutrients in the representation in the no-practice scenario for nutrient management.
** On over half of the cropped acres, more nitrogen volatilization and denitrification occurs with practices than without practices, resulting in a small net gain in nitrogen volatilization and denitrification on average for the region due to conservation practices. In preventing nitrogen loss to other loss pathways, conservation practices keep more of the nitrogen compounds on the field longer, where it is exposed to wind and weather conditions that promote volatilization.
*** Harvest was simulated on acres planted to trees where expected tree age is less than the 47-years included in the model simulation. At tree harvest time, the grass also is removed and replanted.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix C for the 4 subbasins.

**Figure 31**. Estimates of average annual nitrogen lost through various loss pathways, Chesapeake Bay region

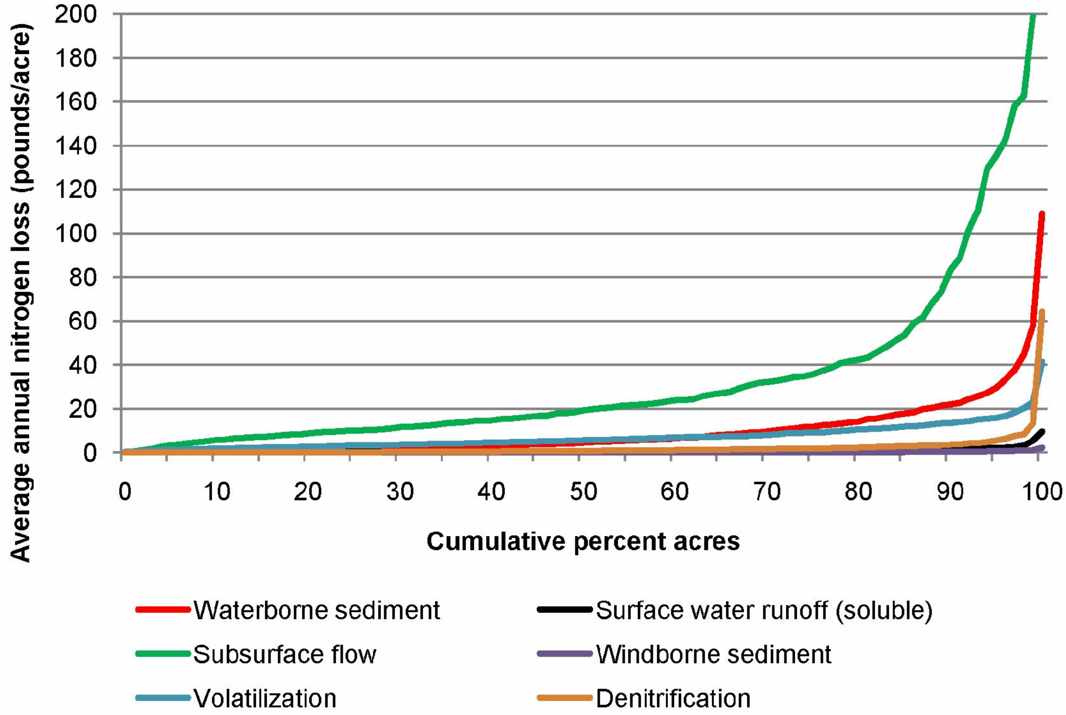



**Figure 32.** Cumulative distributions of the proportion of nitrogen lost through various loss pathways, Chesapeake Bay region

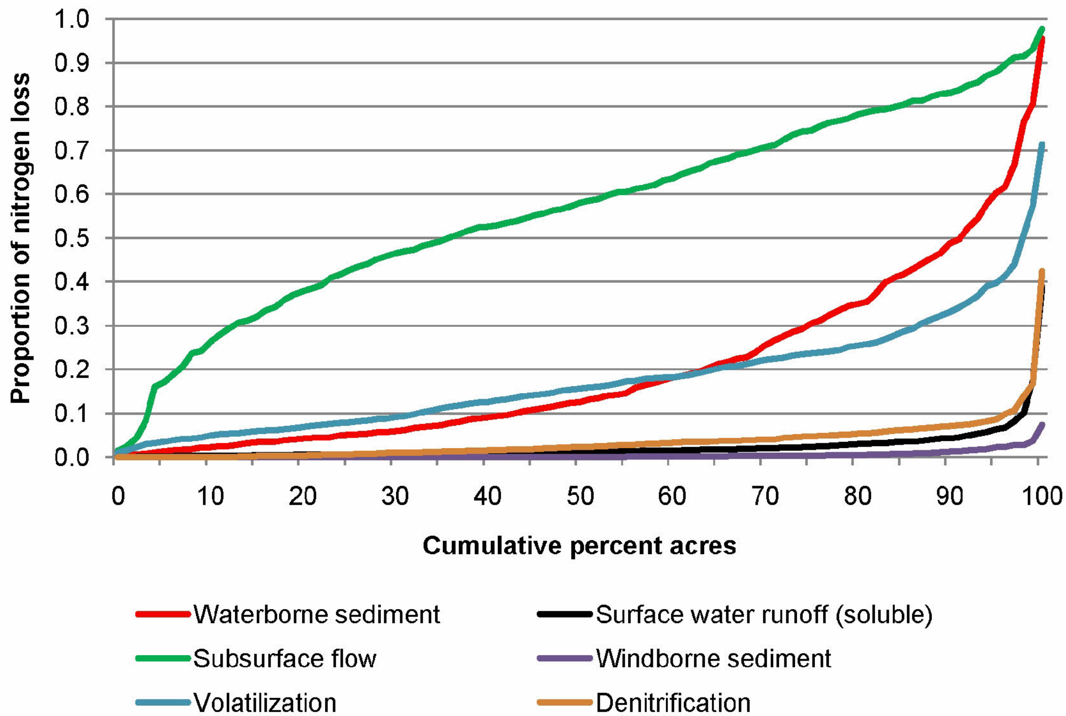
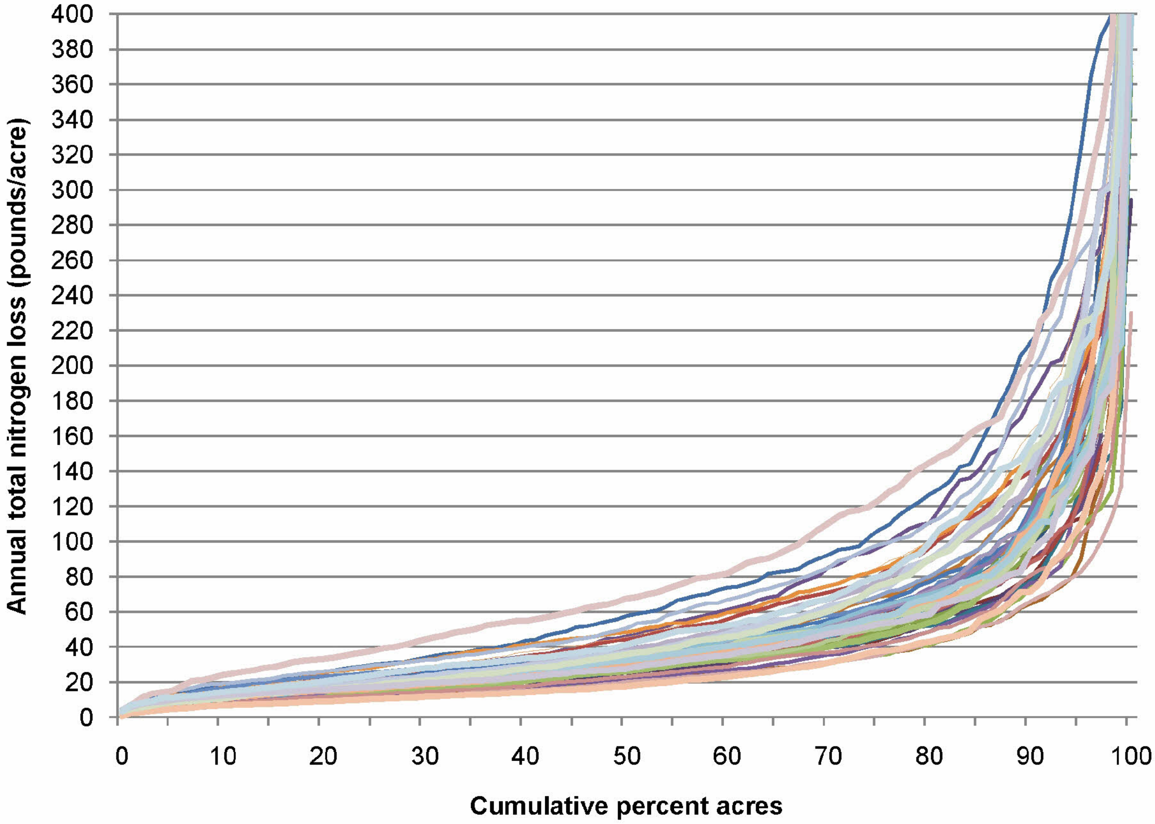


**Figure 33**. Distribution of annual total nitrogen loss for each year of the 47-year model simulation, Chesapeake Bay region




**Note:** This figure shows how annual total nitrogen loss (pounds per acre per year) varied within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual total nitrogen loss varied over the region in that year, starting with the acres with the lowest total nitrogen loss and increasing to the acres with the highest total nitrogen loss. The family of curves shows how annual total nitrogen loss varied from year to year.

**Figure 34**. Estimates of average annual total nitrogen loss for cropped acres in the Chesapeake Bay region

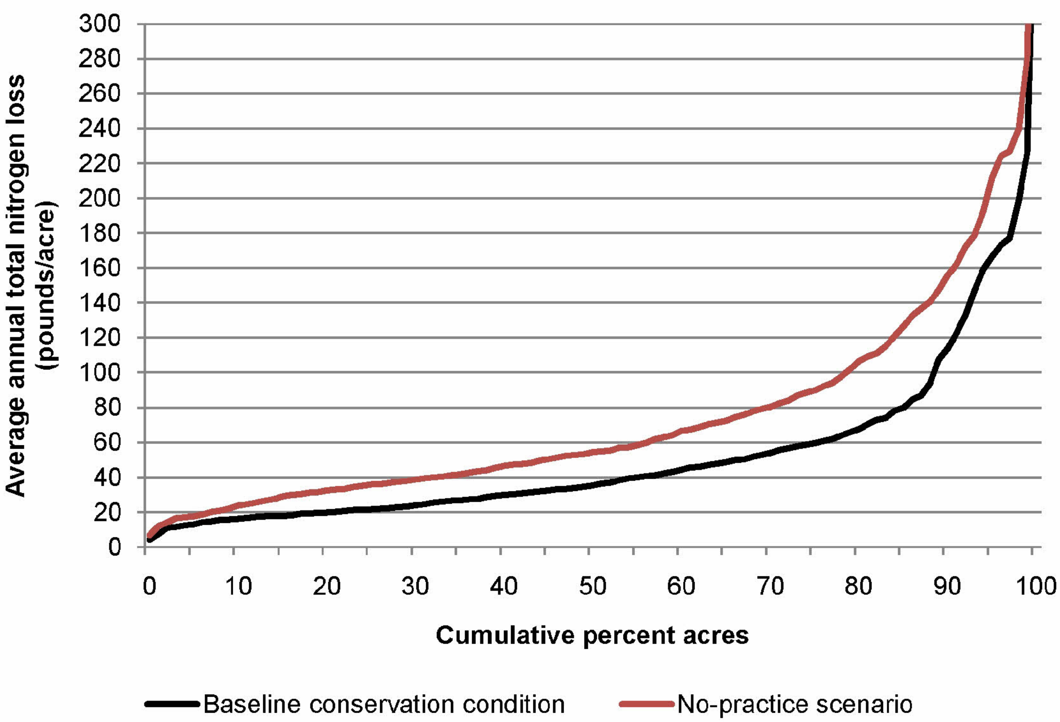
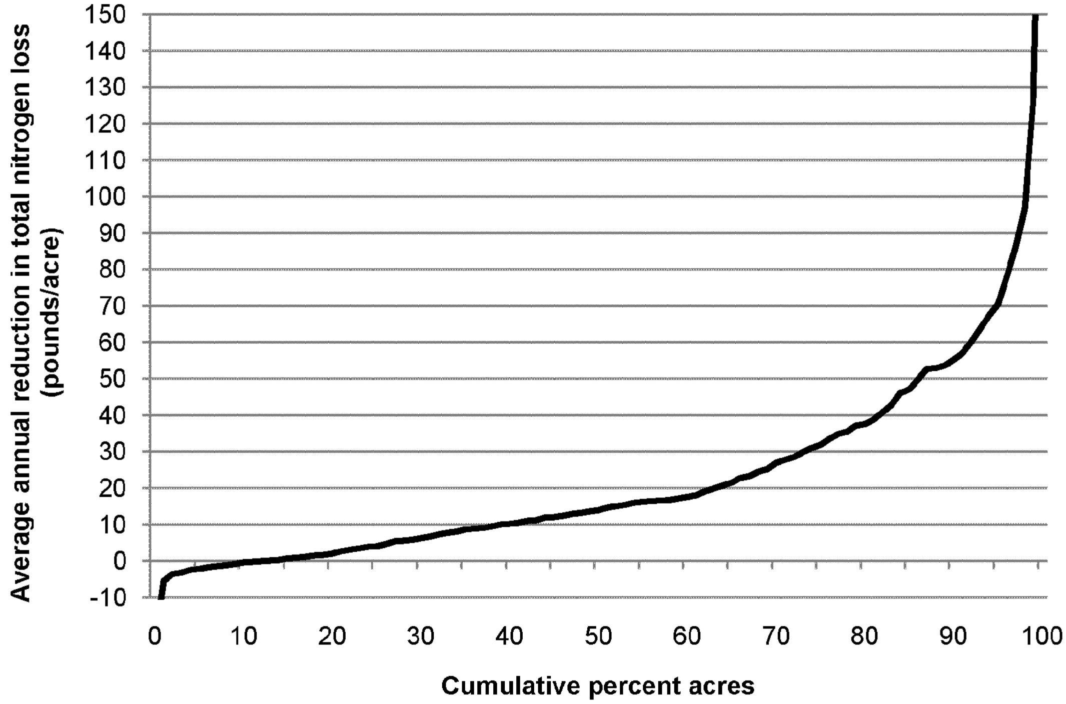


**Figure 35**. Estimates of average annual reduction in total nitrogen loss due to the use of conservation practices on cropped acres in the Chesapeake Bay region




Note: See text for discussion of conditions that result in lower total nitrogen loss in the no-practice scenario than in the baseline conservation condition for 12 percent of the acres.

**Tradeoffs in Conservation Treatment**

Conservation practices applied on cropland are, for the most part, synergistic. The benefits accumulate as more practices are added to the designed systems. However, when only a single resource concern is addressed (such as soil erosion), antagonism between the practices and other resource concerns may occur. That is why it is essential that all resource concerns be considered during the conservation planning process. Most of the time the tradeoffs are much smaller than the magnitude of the primary resource concerns. Common examples are:

- Terraces and conservation tillage are planned to solve a serious water erosion problem. However, in some areas there may be concern about saline seeps at the lower part of the field. The planned practices will solve the erosion problem, but could exacerbate the saline seep problem under some conditions. Ignoring that fact does not make for an adequate conservation plan.
- Conservation tillage is planned for erosion control on a cropland field with a high water table. The reduction in runoff may increase leaching of nitrates into the shallow water table. This potential secondary problem requires additional nutrient management practices to address the concern.
- A nutrient management plan reduces the amount of manure added to a field to reduce the loss of nutrients to surface or groundwater. However, the reduction in organic material added to the field may reduce the soil organic matter or reduce the rate of change in soil organic matter.
- Figure 35 shows that about 12 percent of the acres have an increase in total nitrogen loss due to conservation practice use. This result occurs primarily on soils with relatively high soil nitrogen content and generally low slopes where the surface water runoff is re-directed to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices. For these fields, the nutrient management component of a farmer's conservation plan would need to be enhanced to reduce or eliminate the negative effects of soil erosion control practices on nitrogen loss.

To ensure that proper consideration is given to the effects of conservation practices on *all* of the resource concerns, USDA/NRCS developed a comprehensive planning tool referred to as CPPE (Conservation Practice Physical Effects). The CPPE is included in the Field Office Technical Guide. Conservation planners are expected to use CPPE as a reference to ensure that *all* resource concerns are addressed in conservation plans.

**Figure 36**. Estimates of average annual total nitrogen loss for land in long-term conserving cover in the Chesapeake Bay region

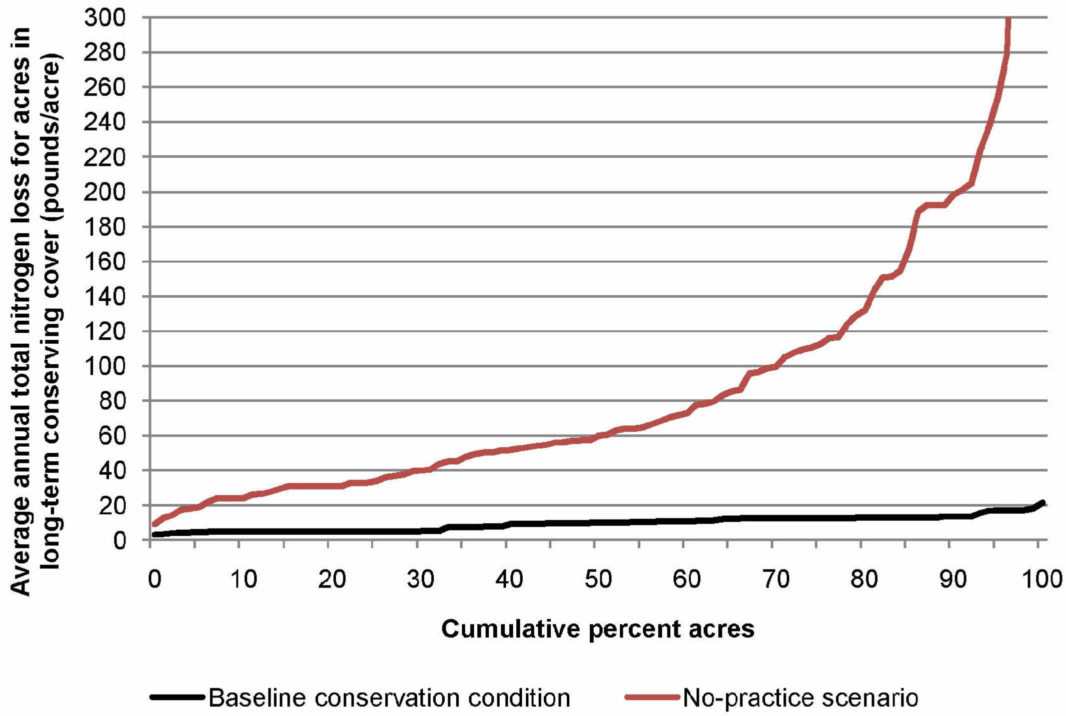



**Figure 37**. Estimates of average annual reduction in total nitrogen loss due to conversion to long-term conserving cover in the Chesapeake Bay region

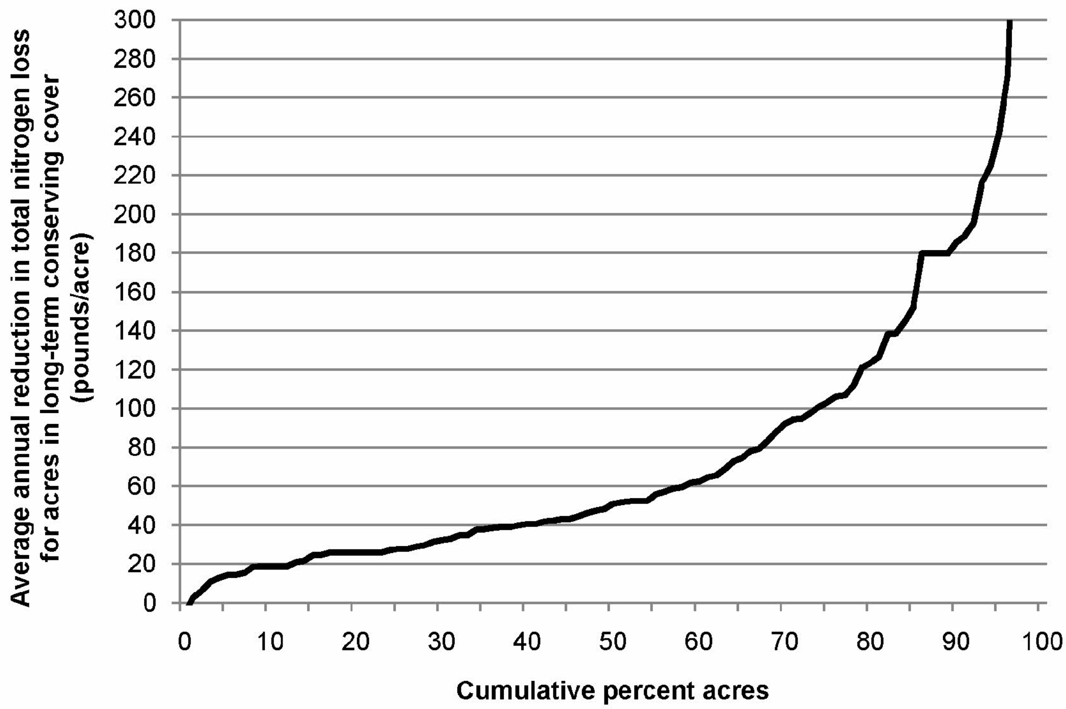


**Figure 38**. Estimates of average annual nitrogen lost with surface runoff (including waterborne sediment) for cropped acres in the Chesapeake Bay region

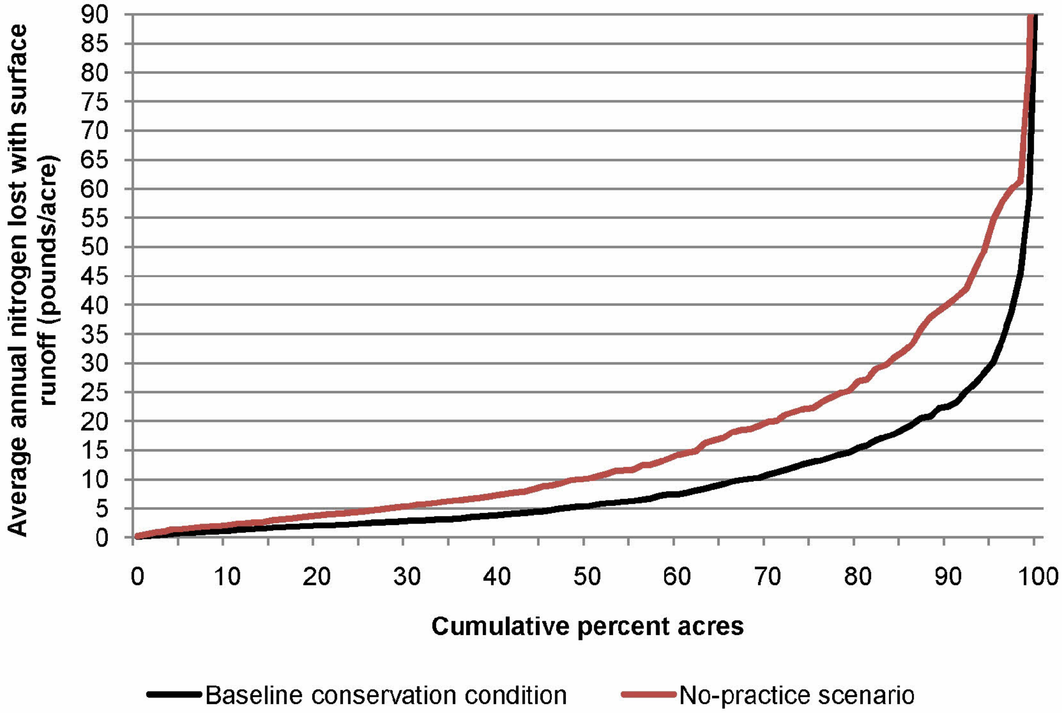
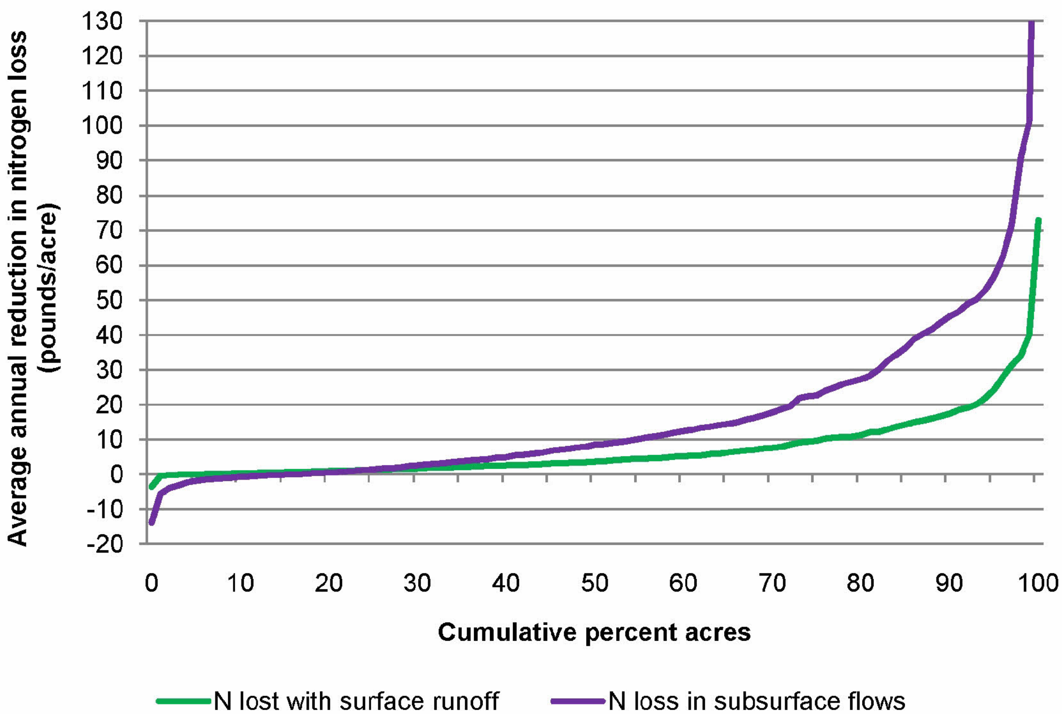
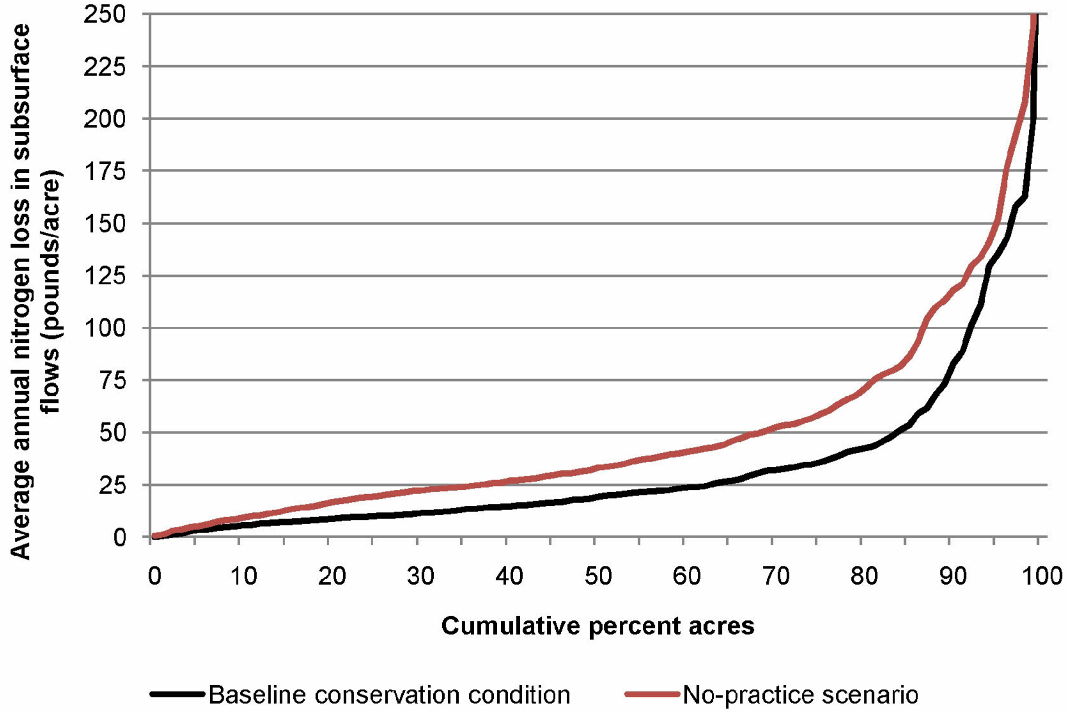



**Figure 39.** Estimates of average annual reduction in nitrogen lost with surface runoff and reduction in nitrogen loss in subsurface flows due to the use of conservation practices on cropped acres in the Chesapeake Bay region




Note: About 2 percent of the acres have negative reductions (net gain) in nitrogen lost with surface runoff due to conservation practices, resulting from a small number of acres with negative reductions in surface water runoff (see figure 19). See text for discussion of negative reductions for loss of nitrogen in subsurface flows.

**Figure 40**. Estimates of average annual nitrogen loss in subsurface flows for cropped acres in the Chesapeake Bay region



## Phosphorus Loss

Phosphorus, like nitrogen, is an essential element needed for crop growth. Unlike nitrogen, however, phosphorus rarely occurs in a gaseous form so the agricultural model has no atmospheric component. Only phosphorus compounds that are soluble in water are available for plants to use. Although total phosphorus is plentiful in the soil, only a small fraction is available at any one time for plant uptake. Farmers apply commercial phosphate fertilizers to supplement low quantities of plant-available phosphorus in the soil.

In the model simulations for the Chesapeake Bay region, about 25 pounds per acre of phosphorus were applied as commercial fertilizer or in manure to cropped acres, on average, in each year of the model simulation (table 19). About half of the phosphorus applied is taken up by the crop and removed at harvest—13 pounds per acre per year, on average.

Total phosphorus loss for all loss pathways other than harvest averaged 3.8 pounds per acre per year in the baseline conservation condition (table 19). These phosphorus loss pathways are—

- phosphorus lost with windborne sediment (average of 0.03 pound per acre per year);
- phosphorus lost with waterborne sediment (average of 2.1 pounds per acre per year);
- soluble phosphorus lost to surface water, including soluble phosphorus in surface water runoff, and soluble phosphorus that infiltrates into the soil profile but quickly returns to surface water either through quick return lateral flow or intercepted by drainage systems (average of 1.6 pounds per acre per year); and
- soluble phosphorus that percolates through the soil profile into the groundwater (average of 0.07 pound per acre per year).

Nearly all phosphorus loss from fields in the Chesapeake Bay region is either with waterborne sediment or soluble phosphorus lost to surface water (figure 41). The percent of phosphorus lost in each loss pathway varies from acre to acre, as shown in figure 42 for cropped acres. The dominant loss pathway for half of cropped acres is phosphorus lost with waterborne sediment. Soluble phosphorus loss with surface water runoff and lateral flow (including discharge to drainage ditches) was the dominant loss pathway for 46 percent of the acres. On average for all acres in the region, 97 percent of the phosphorus lost from fields is lost to surface water (sediment attached and soluble).

As shown for nitrogen, total phosphorus losses are much higher for acres receiving manure than for acres that did not receive manure (table 19). Phosphorus losses are also much higher for highly erodible land than for non-highly erodible land.

Model simulations for the baseline conservation condition indicate that some cropped acres in the Chesapeake Bay region lose much higher amounts of phosphorus than other acres (figure 43). About half of the acres lose less than 4 pounds per acre per year through the various loss pathways other than removal at harvest under *all* weather conditions. About one-fourth of the acres, on the other hand, lose more than 12 pounds per acre in at least some years.

The effects of conservation practices on phosphorus lost to surface water (soluble and sediment attached) are shown in figures 44 and 45 for cropped acres. Conservation practices have reduced total phosphorus loss for cropped acres by 43 percent, reducing the average loss from 6.8 pounds per acre per year if conservation practices were not in use to 3.8 pounds per acre per year for the baseline conservation condition (table 19). With the conservation practices in use as represented by the baseline conservation condition, about 30 percent of cropped acres exceed 4 pounds per acre per year, on average. Without those practices in use, phosphorus lost to surface water would exceed 4 pounds per acre for 53 percent of the acres. The effects of conservation practices on phosphorus lost to surface water vary throughout the Chesapeake Bay region, as shown in figure 45.

For land in long-term conserving cover, total phosphorus loss is 96 percent less than it would have been if crops had been grown and no conservation practices used, reducing total phosphorus loss by 9 pounds per acre per year, on average (table 19, figures 46 and 47).

**Table 19**. Field-level effects of conservation practices on phosphorus sources and phosphorus loss pathways for cropped acres in the Chesapeake Bay region

| Model simulated outcome | Average annual values in pounds per acre: Baseline conservation condition | No-practice scenario | Reduction due to practices | Percent reduction |
|---|---|---|---|---|
| **Cropped acres (4.3 million acres)** | | | | |
| **Phosphorus sources** | | | | |
| Phosphorus applied as commercial fertilizer and manure | 25.1 | 32.7 | 7.6 | 23 |
| **Phosphorus loss pathways** | | | | |
| Phosphorus in crop yield removed at harvest | 13.11 | 14.09 | 0.98 | 7 |
| Phosphorus lost with windborne sediment | 0.03 | 0.08 | 0.04 | 58 |
| Phosphorus lost to surface water (sediment attached and soluble)* | 3.75 | 6.66 | 2.92 | 44 |
| Phosphorus loss with waterborne sediment | 2.10 | 4.42 | 2.32 | 52 |
| Soluble phosphorus lost to surface water (soluble)* | 1.64 | 2.24 | 0.60 | 27 |
| Soluble phosphorus loss to groundwater | 0.07 | 0.07 | 0.00 | 0 |
| Total phosphorus loss for all pathways except harvest | 3.85 | 6.81 | 2.96 | 43 |
| **Change in soil phosphorus** | 8.05 | 11.78 | 3.72 | -- |
| **Highly erodible land (44 percent of cropped acres)** | | | | |
| Phosphorus applied as commercial fertilizer and manure | 27.5 | 33.2 | 5.7 | 17 |
| Total phosphorus loss for all pathways except harvest | 5.64 | 9.54 | 3.91 | 41 |
| **Non-highly erodible land (56 percent of cropped acres)** | | | | |
| Phosphorus applied as commercial fertilizer and manure | 23.1 | 32.2 | 9.0 | 28 |
| Total phosphorus loss for all pathways except harvest | 2.46 | 4.68 | 2.22 | 47 |
| **Acres with manure applied (38 percent of cropped acres)** | | | | |
| Phosphorus applied as commercial fertilizer and manure | 39.2 | 46.2 | 7.0 | 15 |
| Total phosphorus loss for all pathways except harvest | 6.44 | 10.48 | 4.04 | 39 |
| **Acres without manure applied (62 percent of cropped acres)** | | | | |
| Phosphorus applied as commercial fertilizer and manure | 16.5 | 24.4 | 7.9 | 32 |
| Total phosphorus loss for all pathways except harvest | 2.29 | 4.59 | 2.31 | 50 |
| **Land in long-term conserving cover (0.1 million acres)** | | | | |
| **Phosphorus sources** | | | | |
| Phosphorus applied as commercial fertilizer and manure | 0.00 | 34.7 | 34.7 | 100 |
| **Phosphorus loss pathways** | | | | |
| Phosphorus in crop yield removed at harvest | 0.49** | 12.55 | 12.05 | 96 |
| Phosphorus lost with windborne sediment | 0.00 | 0.01 | 0.01 | 100 |
| Phosphorus lost to surface water (sediment attached and soluble)* | 0.19 | 9.21 | 9.02 | 98 |
| Phosphorus loss with waterborne sediment | 0.03 | 6.79 | 6.76 | 100 |
| Soluble phosphorus lost to surface water (soluble)* | 0.17 | 2.42 | 2.25 | 93 |
| Soluble phosphorus loss to groundwater | 0.15 | 0.09 | -0.05 | -58 |
| Total phosphorus loss for all pathways except harvest | 0.34 | 9.31 | 8.97 | 96 |
| **Change in soil phosphorus** | -1.13 | 12.89 | 14.02 | -- |

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

** Harvest was simulated on acres planted to trees where expected tree age is less than the 47-years included in the model simulation. At tree harvest time, the grass also is removed and replanted.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Note: Model simulation results for the baseline conservation condition are presented in appendix C for the 4 subbasins.

**Figure 41**. Estimates of average annual phosphorus lost through various loss pathways, Chesapeake Bay region

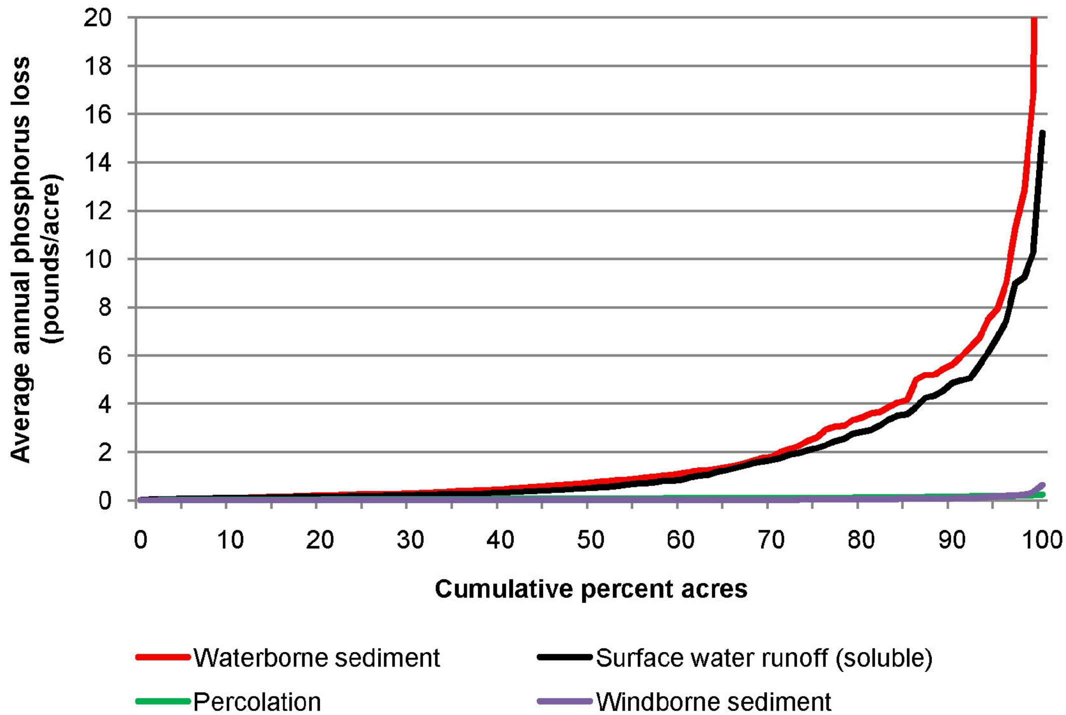



**Figure 42.** Cumulative distributions of the proportion of phosphorus lost through various loss pathways, Chesapeake Bay region

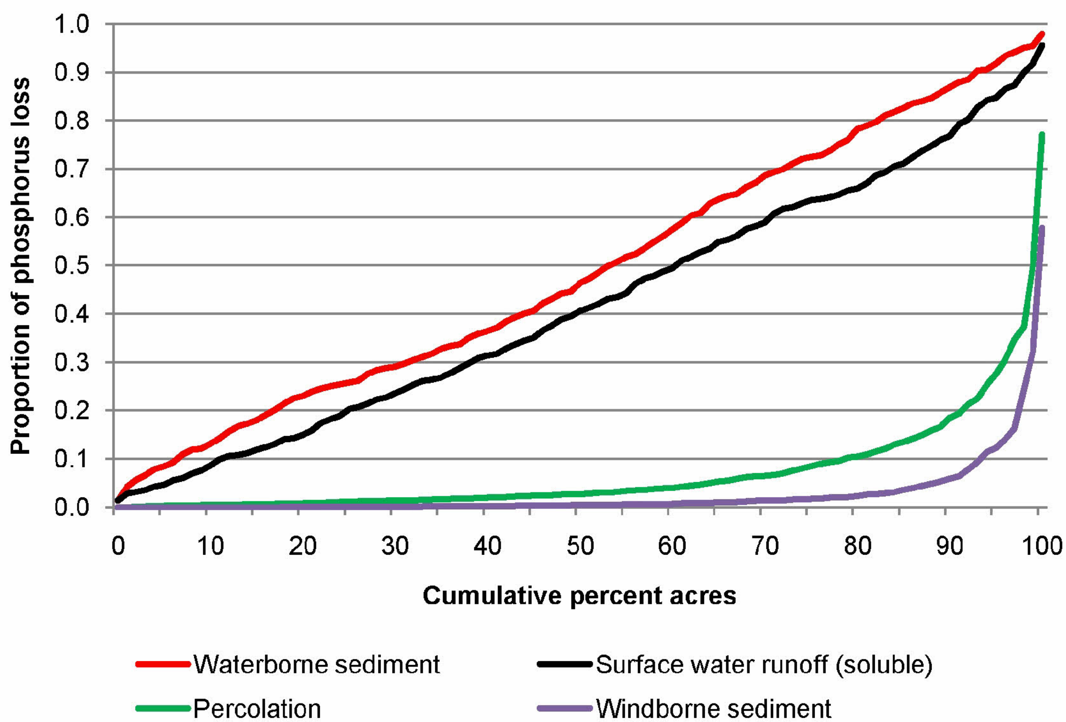
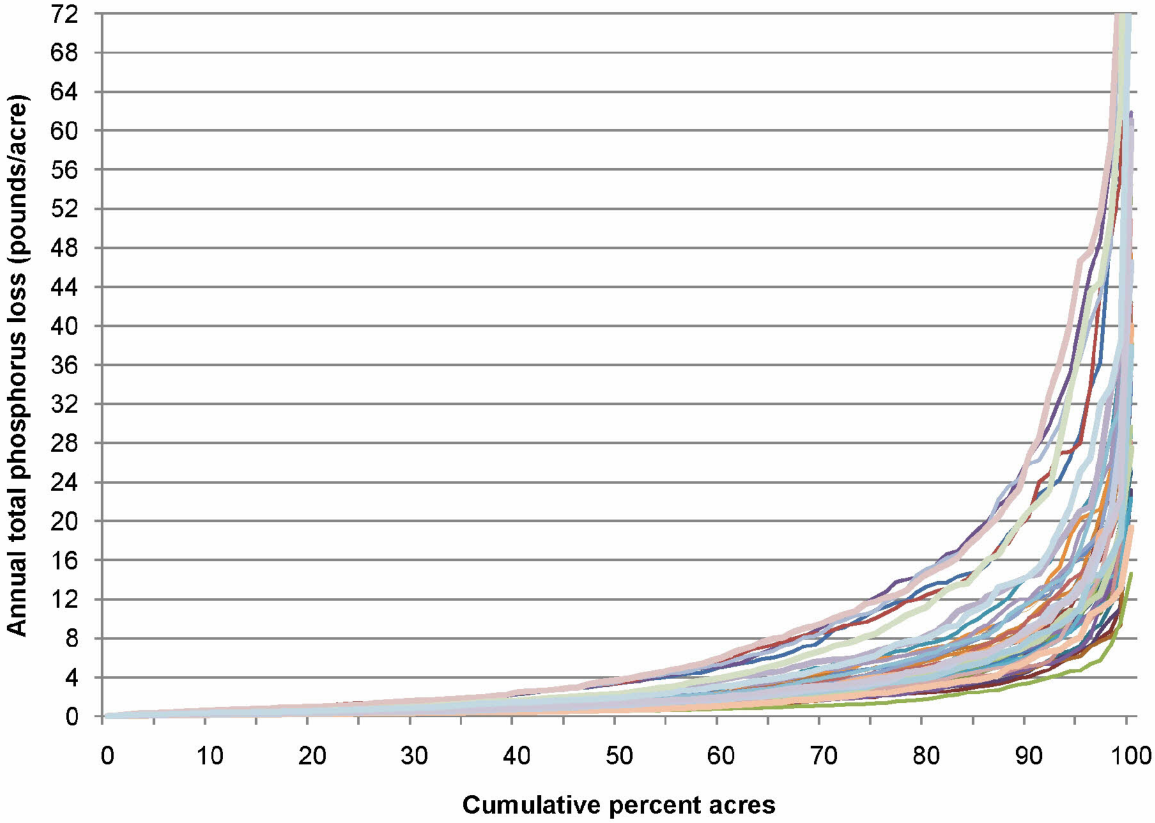
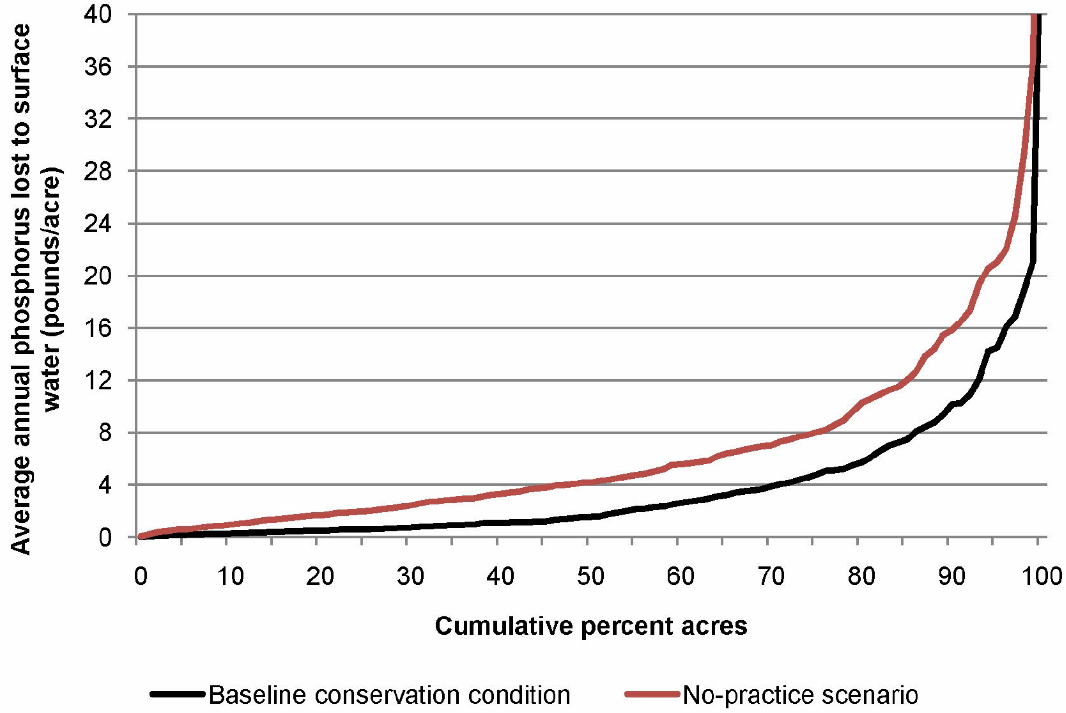


**Figure 43**. Distribution of annual total phosphorus loss for each year of the 47-year model simulation, Chesapeake Bay region



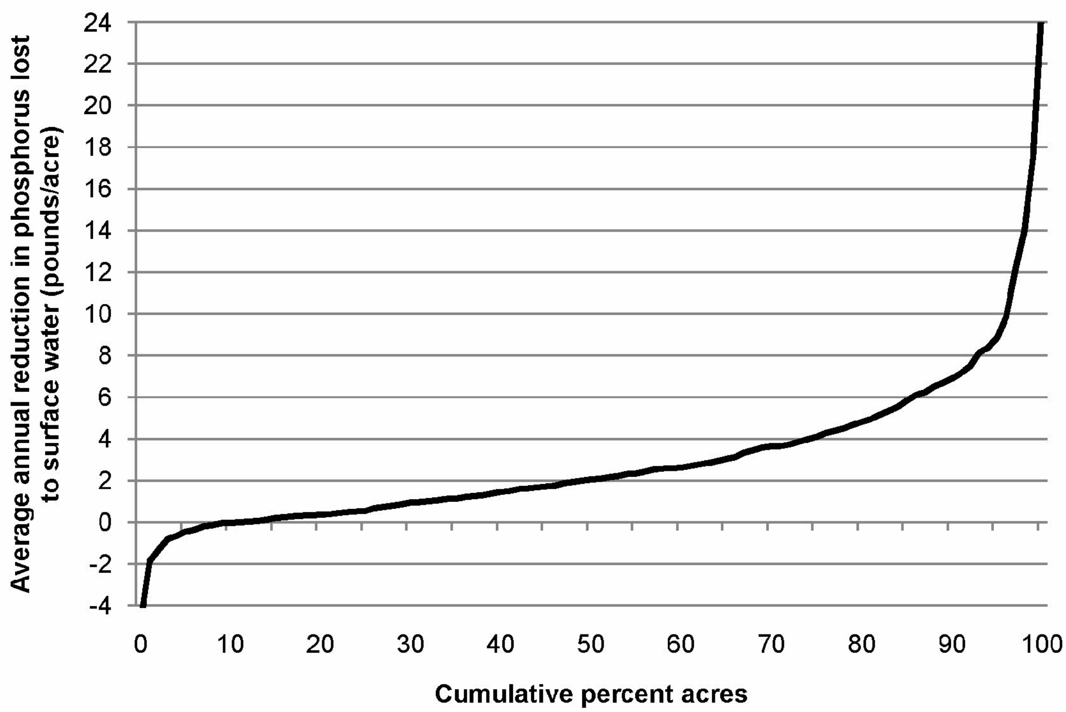

**Note:** This figure shows how annual total phosphorus loss (pounds per acre per year) varied within the region and from year to year in the model simulation on cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual total phosphorus loss varied over the region in that year, starting with the acres with the lowest total phosphorus loss and increasing to the acres with the highest total phosphorus loss. The family of curves shows how annual total phosphorus loss varied from year to year.

**Figure 44**. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble)*for cropped acres in the Chesapeake Bay region




* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

**Figure 45**. Estimates of average annual reduction in phosphorus lost to surface water (sediment attached and soluble) due to conservation practices on cropped acres in the Chesapeake Bay region




Note: Acres with an overall increase in surface water runoff due to conservation practices (see figure 19) causes gains (negative reductions) in phosphorus lost to surface water due to conservation practices greater than 0.1 pounds per acre for about 8 percent of the cropped acres.

**Figure 46**. Estimates of average annual total phosphorus loss for land in long-term conserving cover in the Chesapeake Bay region

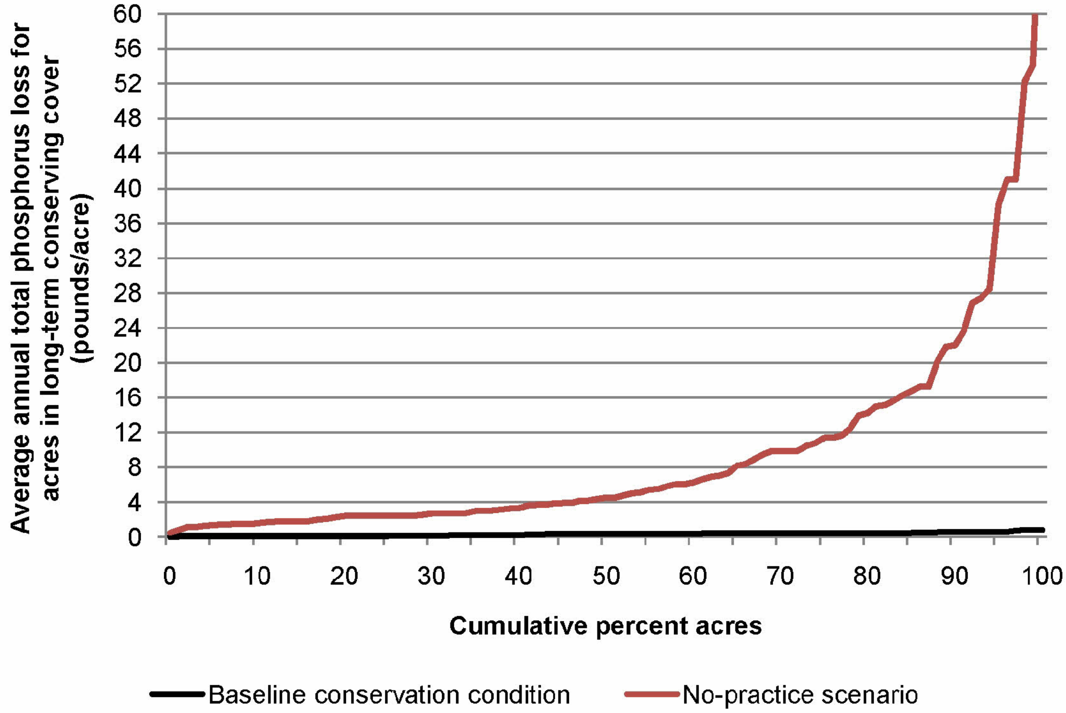
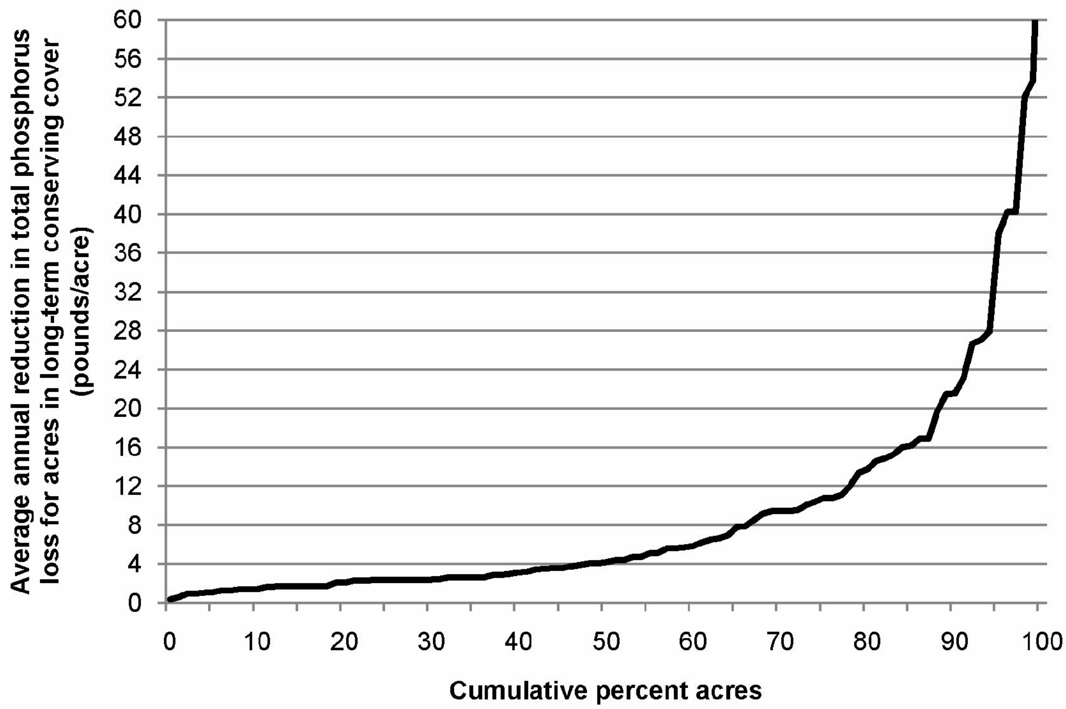



**Figure 47**. Estimates of average annual reduction in total phosphorus loss due to conversion to long-term conserving cover in the Chesapeake Bay region



## Pesticide Residues and Environmental Risk

### Pesticide loss

Use of pesticides to protect crops from weeds, insects, and diseases is an integral part of crop production. While pesticides are essential for large-scale agriculture, pesticide residues can migrate from the application site and lead to unintentional risk to humans and non-target plants and animals. Most pesticides are applied at much lower rates than nutrients. The fraction of pesticides applied that migrates offsite with water is generally less than 1 to 2 percent. Nevertheless, small amounts of pesticide residue can create water quality concerns depending on the toxicity of the pesticide residues to non-target species and even exceed EPA drinking water standards at times.

The APEX model tracks the mass loss of pesticides dissolved in surface water runoff, adsorbed to sediment loss from wind and water erosion, and dissolved in subsurface flow pathways.[21] The distribution of losses through each of these three pathways is shown in figure 48.

For the Chesapeake Bay region, the dominant loss pathway was pesticide lost with waterborne and windborne sediment for 43 percent of cropped acres. Subsurface flow was the dominant loss pathway for 26 percent of the acres; surface water runoff was the dominant pathway for 22 percent of the acres; and 9 percent of the acres had no pesticide loss. Waterborne and windborne sediment accounted for about 51 percent of the total pesticide loss in the baseline conservation condition. Pesticides dissolved in surface water runoff represented 21 percent of the total pesticide mass loss and pesticides in subsurface flows represented 28 percent.

The average annual amount of pesticide lost from farm fields in the Chesapeake Bay region is about 15 grams of active ingredient per hectare per year (table 20).[22] As was observed for sediment and nutrient loss, the majority of pesticide loss occurs on a minority of acres within the Chesapeake Bay region (figure 48). About 68 percent of the acres have total mass loss less than the mean value of 15 grams per hectare. The median loss is 7.7 grams per hectare. About 30 percent of the acres have annual average pesticide mass loss less than 3 grams per hectare. In contrast, about 10 percent of the acres have an annual average pesticide mass loss of more than 35 grams of active ingredient per hectare.

In the model simulations, the pesticide applied in the largest amount throughout the region was atrazine at 24 percent of the total weight of pesticides applied followed closely by glyphosate at 21 percent. The herbicide s-metolachlor represented 14 percent of the total weight of pesticides applied in the region. These three pesticides accounted for 59 percent of the pesticides applied in the region, by weight.

The most common pesticide residues lost from farm fields are atrazine (26 percent of total mass loss) and paraquat dichloride (21 percent of total mass loss) (table 21). Pendimethalin and glyphosate each represented over 10 percent of the total mass loss. These 4 pesticides represented 70 percent of all pesticide residues lost from farm fields in the model simulations.

Pesticide loss for land in long-term conserving cover was not simulated because the survey did not provide information on pesticide use on land enrolled in CRP General Signups. It was assumed that there was no pesticide residues lost from land in long-term conserving cover.

### Environmental risk

Management practices that reduce the potential for loss of pesticides from farm fields consist of a combination of Integrated Pesticide Management (IPM) techniques and water erosion control practices. Water erosion control practices mitigate the loss of pesticides from farm fields by reducing surface water runoff and sediment loss, both of which carry pesticide residues from the farm field to the surrounding environment. IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environmental condition. IPM consists of a management strategy for prevention, avoidance, monitoring, and suppression of pest populations. When the use of pesticides is necessary to protect crop yields, selection of pesticides that have the least environmental risk is an important aspect of the suppression component of IPM.

Model simulations show that conservation practices—primarily water erosion control practices—are effective in reducing the loss of pesticide residues from farm fields. Use of conservation practices has reduced the loss of pesticides (summed over all pesticides) by an average of 8 grams of active ingredient per hectare per year, a 36-percent reduction from the 23 grams per hectare for the no-practice scenario (table 20).

However, the total quantity of pesticide residues lost from the field is not the most useful outcome measure for assessing the environmental benefits of conservation practices. The environmental impact is specific to the toxicity of each pesticide to non-target species that may be exposed to the pesticide.

Pesticide risk indicators were therefore developed to represent risk at the edge-of-the field (bottom of soil profile for groundwater). These edge-of-field risk indicators are based on the ratio of pesticide concentrations in water leaving the field to safe concentrations (toxicity thresholds) for each pesticide. As such, these risk indicators do not have units. The pesticide risk indicators were developed so that the relative risk for individual pesticides could be aggregated over the more than 150 pesticides in use on cropped acres in the Chesapeake Bay region.

[21] The APEX model currently does not estimate pesticides lost in spray drift or volatilization.

[22] Grams per hectare is the standard reporting unit for pesticide active ingredients.

Risk indicator values of less than 1 are considered "safe" because the concentration is below the toxicity threshold for exposure at the edge-of-the field. [23]

Three edge-of-field risk indicators are used here to assess the effects of conservation practices: (1) surface water pesticide risk indicator for aquatic ecosystems, (2) surface water pesticide risk indicator for humans, and (3) groundwater pesticide risk indicator for humans. The surface water risk indicator includes pesticide residues in solution in surface water runoff and in all subsurface water flow pathways that eventually return to surface water (water flow in a surface or tile drainage system, lateral subsurface water flow, and groundwater return flow). The pesticide risk indicator for aquatic ecosystems was based on chronic toxicities for fish and invertebrates, and acute toxicities for algae and vascular aquatic plants. The pesticide risk indicators for humans were based on drinking water standards or the equivalent for pesticides where standards have not been set.

These indicators provide a consistent measure that is comparable from field to field and that represents the effects of farming activities on risk reduction without being influenced by other landscape factors. In most environmental settings, however, non-target species are exposed to concentrations that have been diluted by water from other sources, even when those environments are located adjacent to a field. Consequently, these edge-of-field risk indicators cannot be used to predict actual environmental impacts.

Atrazine was the dominant pesticide contributing to all three risk indicators (table 21). Based on the model simulations, the edge-of-field risk indicator for atrazine exceeded 1 for 27 percent of the cropped acres for risk to aquatic ecosystems, 6 percent of the cropped acres for surface water risk to humans, and 7 percent of the cropped acres for groundwater risk to humans. Atrazine's dominance in the risk indicators is due to its widespread use, its mobility (solubility = 30 mg/L; Koc = 100 g/ml), its persistence (field half life = 60 days), its toxicity to aquatic ecosystems (aquatic plant toxicity = 1 ppb), and the human drinking water standard (EPA Maximum Contaminant Level = 3 ppb).

The pesticide risk indicator for aquatic ecosystems averaged 1.5 over all years and cropped acres (table 20) for the baseline conservation condition. (The 1.5 value indicates that pesticide concentrations in water leaving cropped fields in the Chesapeake Bay region are, on average, 1.5 times the "safe" concentration for non-target plant and animal species.) The median value, however, is only 0.6, indicating that the risk indicator for half of the acres is less than 0.6 and greater than 0.6 for half of the acres. Figure 49 shows that for most years the overall risk for aquatic ecosystems is very low (below 1 for over half of the acres in all years), in part because of the conservation practices in use, but in some years the edge-of-field concentrations can be high relative to "safe" thresholds.

The pesticide risk indicators for humans were much lower, averaging 0.3 for surface water and for groundwater. The median values are 0.17 for surface water and 0.08 for groundwater. Only about 8 percent of the cropped acres have an average annual edge-of-field surface water pesticide risk indicator for humans or an average annual bottom-of-the-rootzone groundwater pesticide risk indicator more than 1.

The use of conservation practices in the Chesapeake Bay region has reduced the pesticide risk indicators by 30 to 34 percent (table 20), averaged over all years, all pesticides, and all cropped acres.

The distributions of the surface water pesticide risk indicators are shown in figures 50 and 51. Figure 52 shows the distribution of the reductions in the two pesticide risk indicators due to conservation practices. The benefits of conservation practices were significant for both aquatic risks and human risks on the acres that had those risks, but aquatic risks were more widespread than human risks so conservation practices have greater total benefit for aquatic ecosystems than for human drinking water.

[23] A threshold value of 1 for the pesticide risk indicator applies when assessing the risk for a single pesticide. Since the indicator is summed over all pesticides in this study, a threshold value of 1 would still apply if pesticide toxicities are additive and no synergistic or antagonistic effects are produced when non-target species are exposed to a mix of pesticides. For more information on the derivation of the pesticide risk indicators, see "Pesticide risk indicators used in the CEAP cropland modeling," found at http://www.nrcs.usda.gov/technical/nri/ceap/cropland.html.

**Table 20**. Field-level effects of conservation practices on pesticide loss and associated edge-of-field environmental risk for cropped acres in the Chesapeake Bay region

| Model simulated outcome | Baseline conservation condition | No-practice scenario | Reduction due to practices | Percent reduction |
|---|---|---|---|---|
| **Pesticide sources** | | | | |
| Average annual amount of pesticides applied (grams of active ingredient/hectare) | 2000 | 2318 | 319 | 14 |
| **Pesticide loss** | | | | |
| Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare) | 15 | 23 | 8 | 36 |
| **Edge-of-field pesticide risk indicator** | | | | |
| Average annual surface water pesticide risk indicator for aquatic ecosystem | 1.47 | 2.23 | 0.75 | 34 |
| Average annual surface water pesticide risk indicator for humans | 0.34 | 0.49 | 0.15 | 30 |
| Average annual groundwater pesticide risk indicator for humans | 0.34 | 0.49 | 0.15 | 30 |

Note: It was assumed that no pesticides were applied to land in long-term conserving cover and there was no data on residual pesticides in the soil for these acres; thus, the assessment of the effects of this practice on pesticide loss was not done.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix C for the 4 subbasins.

**Figure 48.** Estimates of average annual pesticide loss (mass loss of all pesticides combined) for total loss and for three loss pathways, Chesapeake Bay region

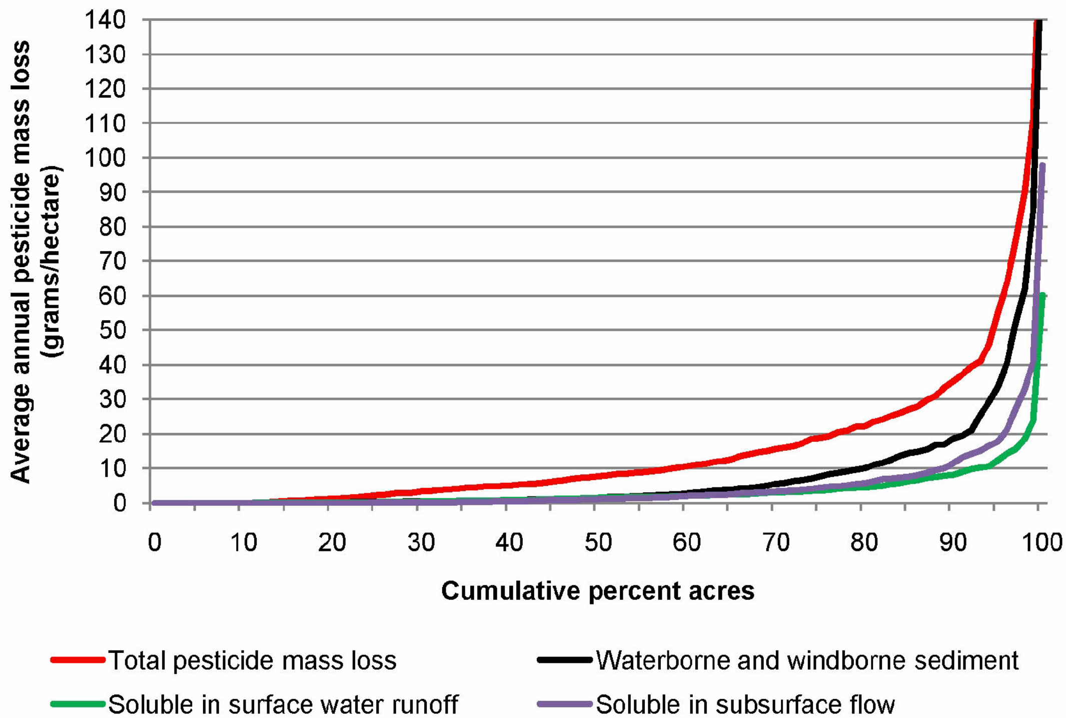
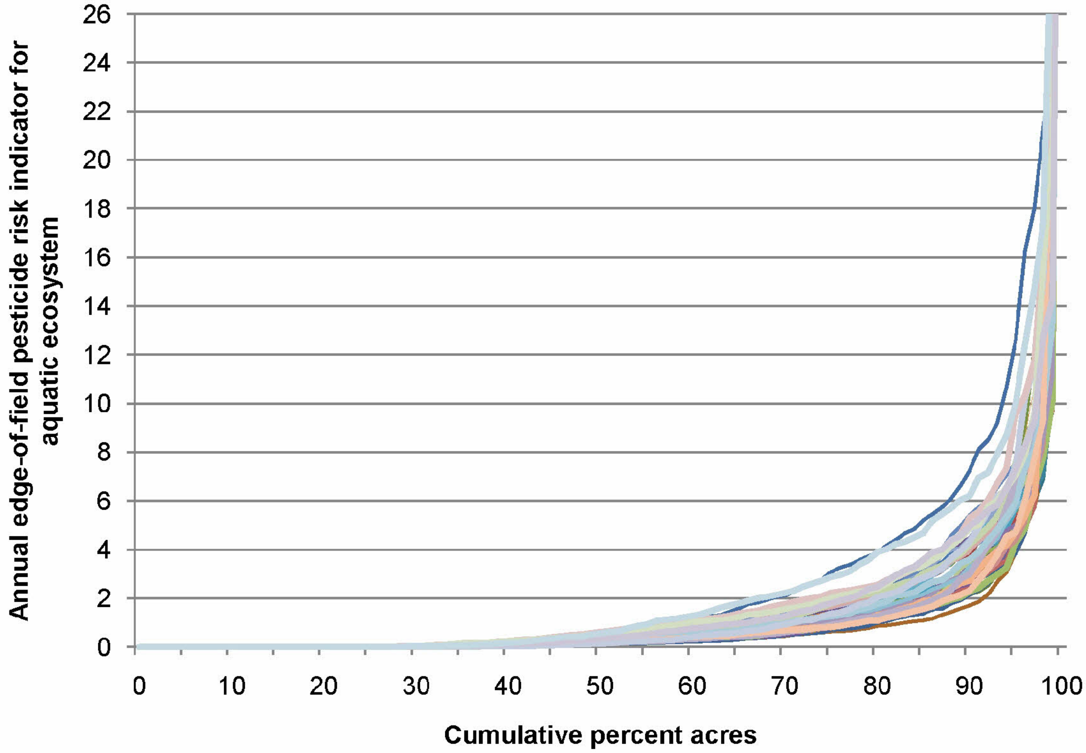


**Table 21.** Dominant pesticides applied in model simulations, dominant pesticides contributing to losses, and dominant pesticides in determining edge-of-field environmental risk, Chesapeake Bay region

| Pesticide (active ingredient name) | Pesticide type | Percent of total applied in the region |
|---|---|---|
| **Pesticide application*** | | |
| Atrazine | Herbicide | 24 |
| Glyphosate, isopropylamine sal | Herbicide | 21 |
| S-Metolachlor | Herbicide | 14 |
| Simazine | Herbicide | 6 |
| Pendimethalin | Herbicide | 5 |
| Metolachlor | Herbicide | 4 |
| Acetochlor | Herbicide | 4 |
| Paraquat dichloride | Herbicide | 3 |
| 2,4-D, 2-ethylhexyl ester | Herbicide | 1 |
| Glyphosate | Herbicide | 1 |
| Alachlor | Herbicide | 1 |
| Metam-sodium | Multi-purpose | 1 |
| Glyphosate-trimesium | Insecticide | 1 |
| 1,3-Dichloropropene | Fungicide | 1 |
| Total | | 88 |
| | | Percent of total pesticide loss in the region** |
| **Pesticide loss from farm fields*** | | |
| Atrazine | Herbicide | 26 |
| Paraquat dichloride | Herbicide | 21 |
| Pendimethalin | Herbicide | 13 |
| Glyphosate, isopropylamine sal | Herbicide | 10 |
| S-Metolachlor | Herbicide | 7 |
| Simazine | Herbicide | 5 |
| Metolachlor | Herbicide | 4 |
| Sulfentrazone | Herbicide | 3 |
| Trifluralin | Herbicide | 1 |
| Total | | 90 |
| | | Percent of cropped acres in the region with average annual edge-of-field risk indicator greater than 1 |
| **Risk indicator for aquatic ecosystem** | | |
| Atrazine | Herbicide | 27 |
| Metolachlor | Herbicide | 4 |
| Sulfentrazone | Herbicide | 2 |
| Phostebupirim | Insecticide | <1 |
| Linuron | Herbicide | <1 |
| 2,4-D 2-ethylhexyl ester | Herbicide | <1 |
| All others combined | | 2 |
| **Risk indicator for humans, surface water** | | |
| Atrazine | Herbicide | 6 |
| Simazine | Herbicide | <1 |
| Alachlor | Herbicide | <1 |
| Dimethoate | Insecticide | <1 |
| All others combined | | <1 |
| **Risk indicator for humans, groundwater** | | |
| Atrazine | Herbicide | 7 |
| Simazine | Herbicide | <1 |
| All others combined | | <1 |

* Pesticides not listed each represented less than 1 percent of the total.
** Includes loss of pesticides dissolved in surface water runoff, adsorbed to sediment loss from water erosion, and dissolved in subsurface flow pathways.

**Figure 49**. Distribution of annual values of the edge-of-field surface water pesticide risk indicator for aquatic ecosystems for each year of the 47-year model simulation, Chesapeake Bay region




**Note:** This figure shows how the annual values of the risk indicator varied within the region and from year to year in the model simulation on cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual values of the risk indicator varied over the region in that year, starting with the acres with the lowest value and increasing to the acres with the highest value. The family of curves shows how annual values varied from year to year.

**Figure 50**. Estimates of average annual edge-of-field surface water pesticide risk indicator for aquatic ecosystem in the Chesapeake Bay region

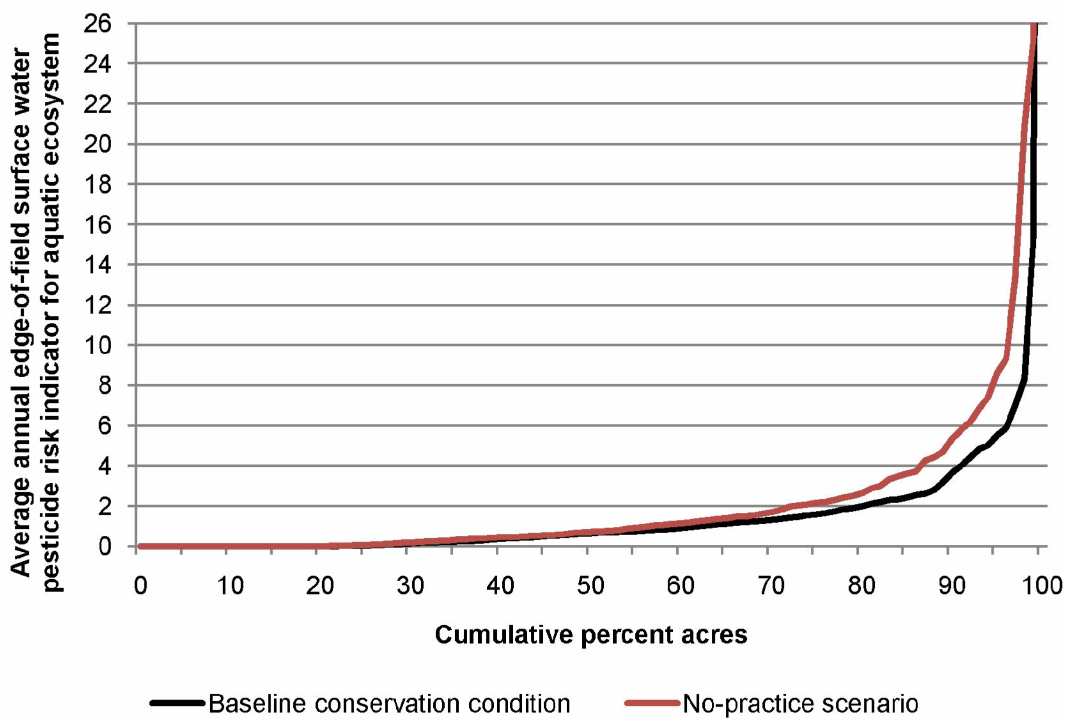


**Figure 51**. Estimates of average annual edge-of-field surface water pesticide risk indicator for humans in the Chesapeake Bay region

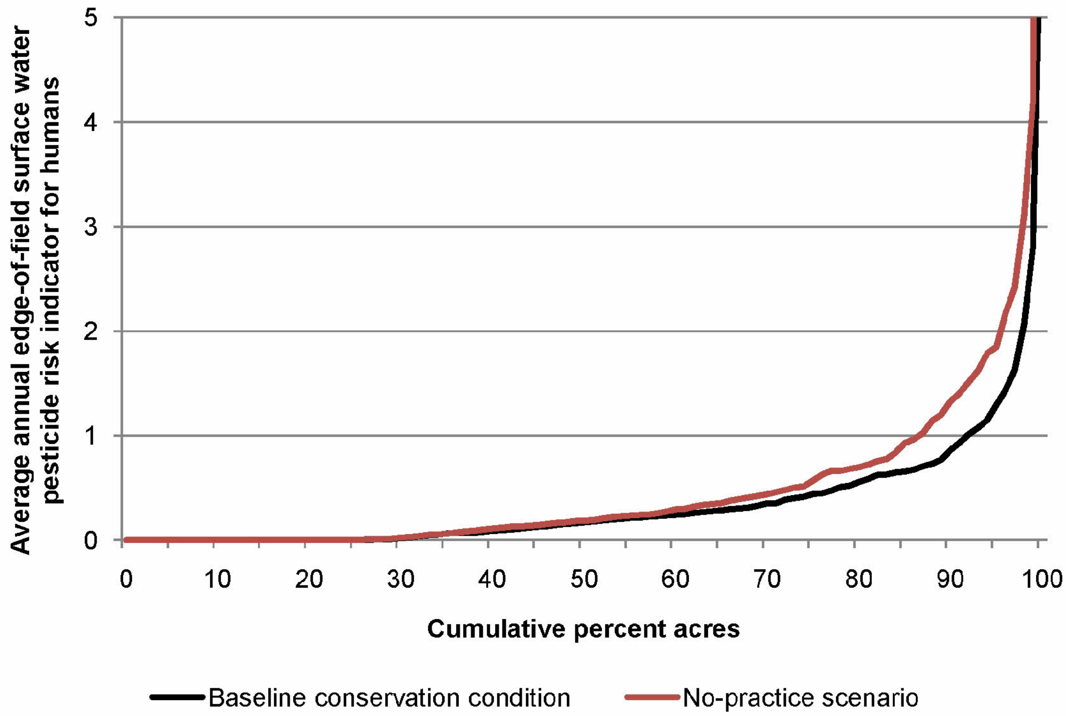
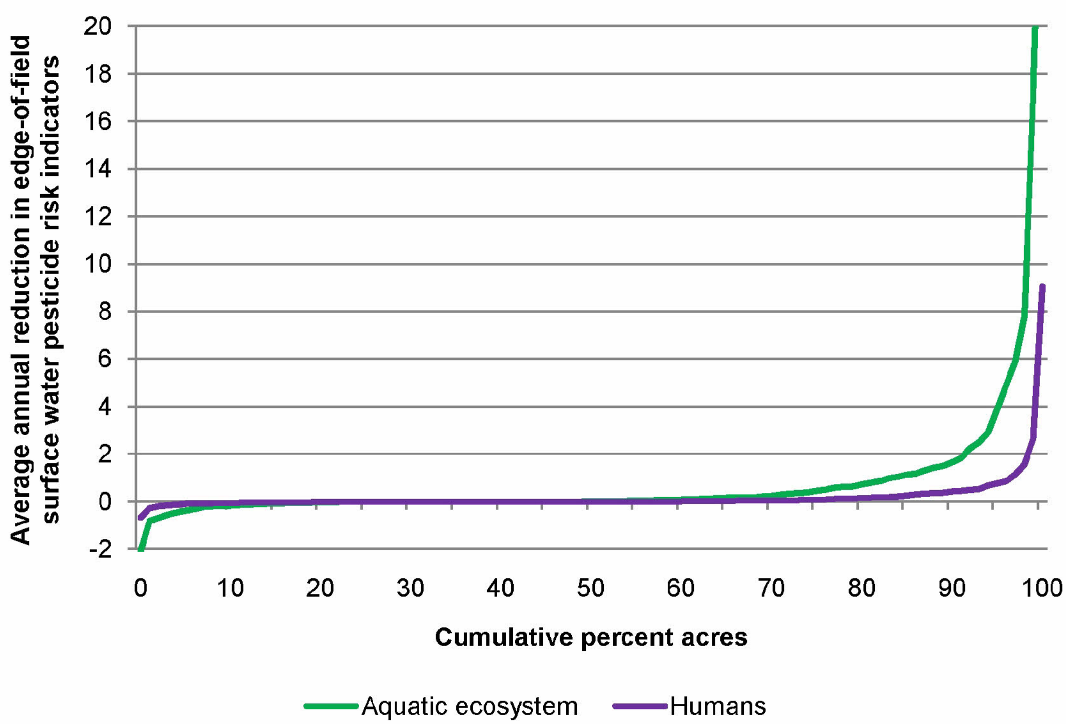



**Figure 52**. Estimates of average annual reductions in the edge-of-field surface water pesticide risk indicators for aquatic ecosystems in the Chesapeake Bay region




Note: Negative reductions in pesticide risk indicators result primarily from an increase in surface water runoff due to conservation practices (see figure 19).

# Chapter 5
# Offsite Water Quality Effects of Conservation Practices

The results from the onsite APEX model simulations for cultivated cropland, including land in long-term conserving cover, were integrated into HUMUS/SWAT to assess the effects of conservation practices on instream loads of sediment, nitrogen, phosphorus, and atrazine.

HUMUS/SWAT accounts for the transport of water, sediment, pesticides, and nutrients from the land to receiving streams and routes the flow downstream to the next watershed and ultimately to estuaries and oceans. Not all of the sediment, nutrients, and pesticides that leave farm fields is delivered to streams and rivers. Some material is bound up permanently in various parts of the landscape during transport. In addition, instream degradation processes and streambed deposition and accumulation remove or trap a portion of the sediment, nutrients, and pesticides after delivery to streams and rivers.

The effects of conservation practices on water quality were assessed by comparing HUMUS/SWAT model simulation results for the baseline conservation condition to simulation results for the no-practice scenario. For each scenario, only the conditions for cultivated cropland were changed, as described previously. All other aspects of the simulations—including sediment and nutrient loads from point sources and land uses other than cultivated cropland—remained the same.

## Source loads and instream loads

All source loads are introduced into SWAT at the outlet of each watershed (8-digit hydrologic unit code [HUC]). Flows and source loads from upstream watersheds are routed through each downstream watershed, including reservoirs when present. There are four points in the modeling process at which source loads or instream loads are assessed, shown in the schematic in figure 53 for sediment.

1. Edge-of-field loads from cultivated cropland—aggregated APEX model output as reported in the previous chapter. (Edge-of-field loads for the Chesapeake Bay watershed differ slightly from those reported in the previous chapter because two 8-digit HUCS that drain to the Atlantic Ocean were excluded and loads from land in long-term conserving cover were included.)

2. Delivery to the watershed outlet from cultivated cropland—aggregated edge-of-field loads after application of delivery ratios. Loadings delivered to streams and rivers differ from the amount leaving the field because of losses during transport from the field to the stream. Delivery ratios are used to make this adjustment.

3. Delivery to the watershed outlet from land uses other than cultivated cropland as simulated by SWAT, after application of delivery ratios. Point sources are included.

4. Loadings in the stream or river at a given point. Instream loads include loadings delivered to the watershed outlet from all sources as well as loads delivered from upstream watersheds, after accounting for channel and reservoir processes.

A sediment delivery ratio was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The sediment delivery ratio used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU.[24]

The sediment delivery ratio in addition to an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentration from the edge of field divided by the concentration at the watershed outlet. As sediment is transported from the edge of field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

Delivery of surface water and subsurface water from upland processes (HRUs and CEAP sample points) was spatially calibrated for each watershed to ensure that water inputs to the SWAT model were in balance with long-term data on streamflow for the region. Water yields from HRUs and sample points were compared to long-term water yields estimated by USGS. Hydrologic parameters in APEX

[24] For a complete documentation of delivery ratios used for the Chesapeake Bay region, see "Delivery Ratios Used in CEAP Cropland Modeling" at http://www.nrcs.usda.gov/technical/nri/ceap/cropland.html.

(cultivated cropland) and SWAT (HRUs) were adjusted separately for each 8-digit watershed until differences in the long-term water yield were minimized.[25]

An additional scenario was conducted to represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by simulating a grass-and-tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.[26] Thus, "background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources. The results of this scenario are labeled "background" in tables and figures.

For reporting, edge-of-field loads and source loads were aggregated over the 8-digit HUCs to the four subbasins in the region (4-digit HUCs). Figure 54 shows the location of each subbasin and the 8-digit HUCs included in each. For the Susquehanna River and the Potomac River (8-digit HUC groups I and III), instream loads represent the loads at the outlet of the subbasin. For the Upper Chesapeake (8-digit HUC group II), the instream loads represent sum of the loads at the outlets of 8-digit HUCs draining to into Bay in subbasin 0206. For the Lower Chesapeake (8-digit HUC groups IV), instream loads represent the sum of the loads at the outlets of Rappahannock, York and James Rivers in subbasin, 0208. For the Lower Chesapeake (8-digit HUC group V), instream loads represent the load at the outlet of the Lower Eastern 8-digit HUC (0208109).

[25] For a complete documentation of calibration procedures and results for the Chesapeake Bay region, see "Calibration and Validation for CEAP HUMUS" at http://www.nrcs.usda.gov/technical/nri/ceap/cropland.html.
[26] In a natural ecosystem, the vegetative cover would include a mix of species, which would continually change until a stable ecosystem was established. APEX allows for multiple species and simulates plant competition over time according to plant growth, canopy cover, vegetative form, and relative maturity or growth stage. The initial mix of species at the beginning of the 47-year simulation was similar to the mix of grasses and trees used to establish long-term conserving cover. Mixes included at least one grass and one legume. Over the 47-year simulation, the mix of grasses and trees shifted due to plant competition. The grass species typically dominate in the simulation until shaded out by tree cover. For further details on how the background simulation was conducted, see "Assumptions and Procedures for Simulating the Natural Vegetation Background Scenario for Cropland" at http://www.nrcs.usda.gov/technical/nri/ceap/cropland.html.

**Figure 53.** Schematic of sediment sources and delivery as modeled with HUMUS/SWAT for the Chesapeake Bay watershed

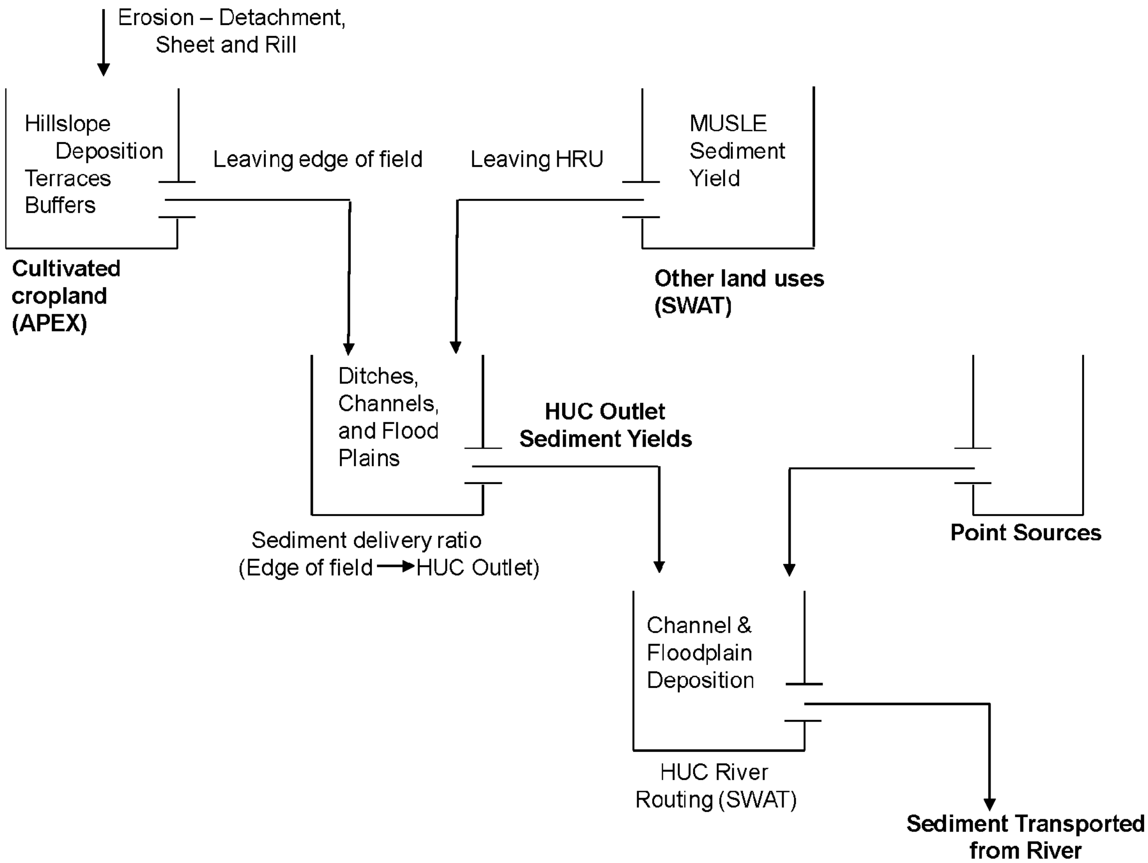
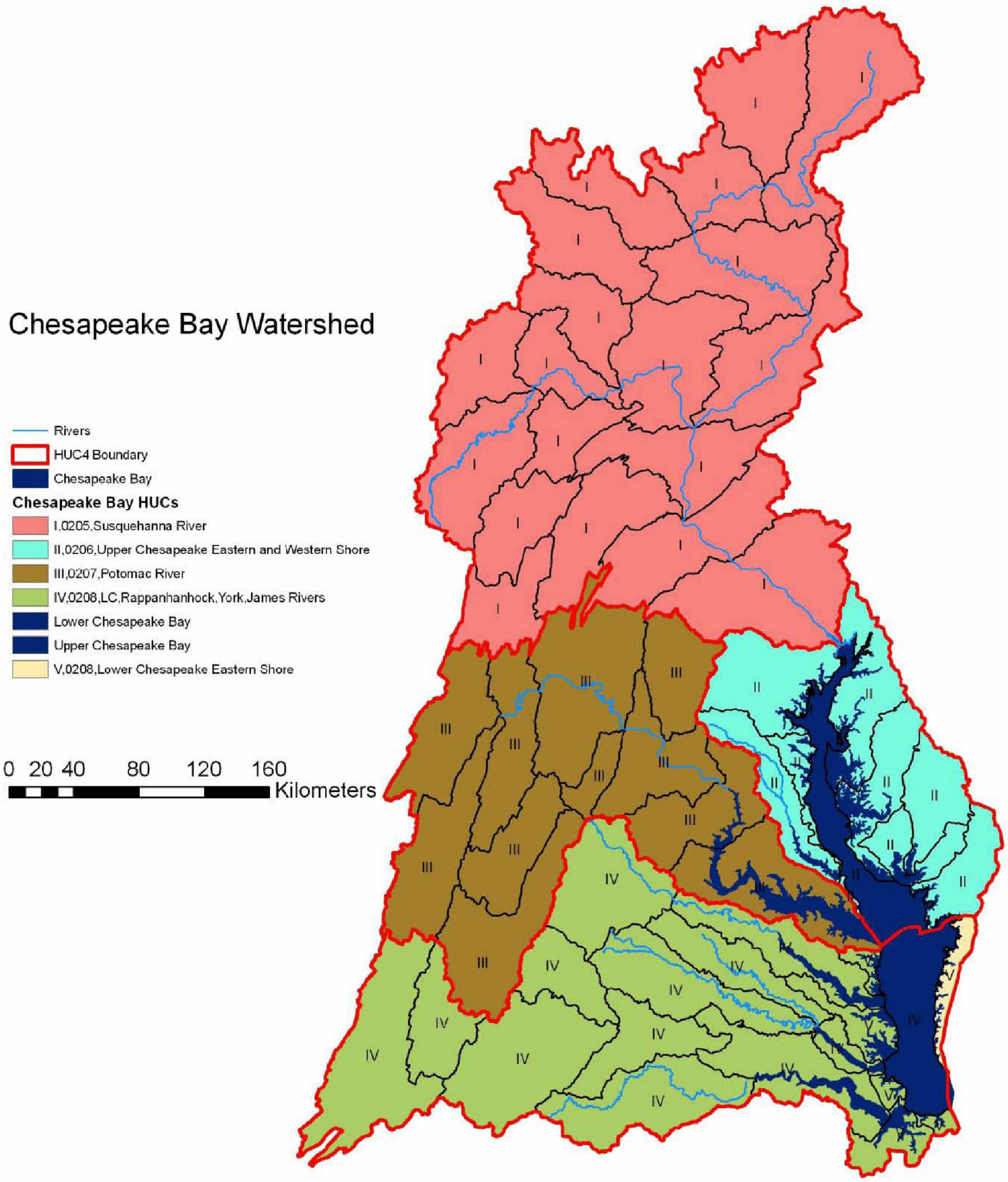


**Figure 54**. Subbasins and 8-digit HUC groups used for reporting of source loads and instream loads for the Chesapeake Bay watershed



## Sediment

Model simulation results show that of the 6.6 million tons of sediment exported from farm fields in the Chesapeake Bay watershed (table 22), about 2.4 million tons are delivered to rivers and streams each year (table 23), on average, under conditions represented by the baseline conservation condition, which includes farming activities and conservation practices in use during 2003-2006. Most (about 73 percent) of the sediment from cultivated cropland originates in the Susquehanna River subbasin. Sediment delivered to rivers and streams from cultivated cropland represents about 25 percent of the total sediment load delivered from all sources (table 24, figure 55). Runoff from urban land, including point sources and construction sites, represents about 38 percent of the total load delivered to streams and rivers.

Instream loads—the amount of sediment delivered to the Bay after accounting for instream deposition and transport processes—totals about 6.85 million tons from all sources, averaged over the 47 years of weather as simulated in the model (table 25, figure 56). Overall, about 8 percent of these instream loads delivered to the Bay are attributable to cultivated cropland sources.

Loads from all sources delivered to the Bay were greatest for the Potomac River and the Lower Chesapeake Bay (figure 56), in part because of their close proximity to the Bay, which reduces opportunities for deposition during transport. Reservoirs in the Susquehanna River basin trap much of the sediment from cultivated cropland in that subbasin, preventing it from being transported to the bay. Although Susquehanna River subbasin delivers more sediment from cultivated cropland (tables 23-24) compared to the Potomac River, the instream sediment load reported at the outlet of Susquehanna River (subbasin 0205) is less than the instream load for the Potomac River (subbasin 0206) because of the Conowingo Reservoir, located just above the outlet of the Susquehanna River.

Sediment loads delivered to streams and rivers would have been much larger if soil erosion control practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of sediment from fields to rivers and streams by about 63 percent (table 23), on average, and reduced delivery of sediment to the Bay by about 14 percent (table 25, figure 56). Without conservation practices, the total sediment delivered to the Bay from all sources would be larger by over 1 million tons (table 25) per year. The Upper Chesapeake subbasin has the highest percent reduction in instream loads delivered to the Bay due to conservation practices—31 percent. This subbasin also has the highest proportion of instream sediment loads attributed to cultivated cropland sources (16 percent).

**Figure 55**. Percentage by source of average annual sediment loads delivered to rivers and streams in the Chesapeake Bay watershed

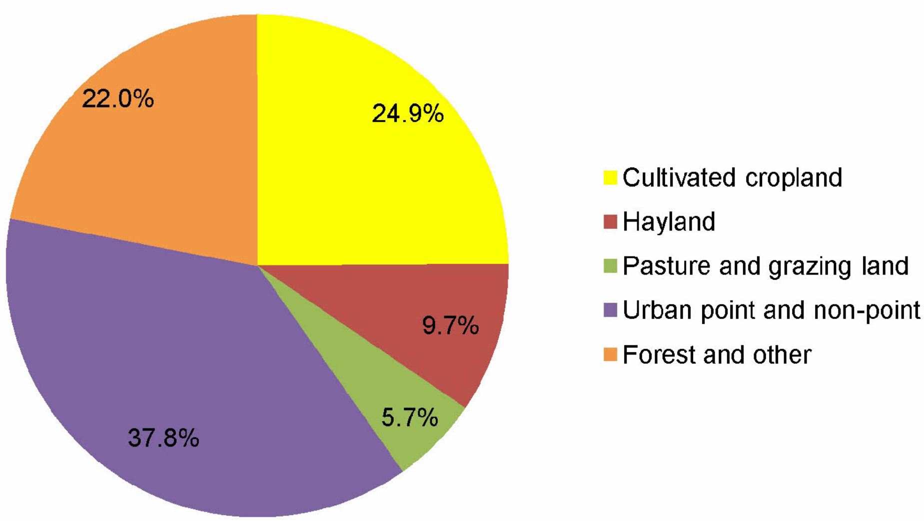


**Table 22.** Average annual sediment loads ***delivered to edge of field*** (APEX model output) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | | | | Reductions in loads due to conservation practices | |
|---|---|---|---|---|---|---|---|---|
| 8-digit HUC group* | Sub-basin code | Subbasin name | Amount (1,000 tons) | Percent of basin total | Tons delivered per cropland acre | No-practice Scenario (1,000 tons) | Reduction (1,000 tons) | Percent |
| I | 0205 | Susquehanna River | 4,852 | 73 | 2.42 | 11,821 | 6,969 | 59 |
| II | 0206 | Upper Chesapeake** | 675 | 10 | 0.55 | 2,562 | 1,887 | 74 |
| III | 0207 | Potomac River | 728 | 11 | 1.19 | 2,453 | 1,725 | 70 |
| IV + V | 0208 | Lower Chesapeake** | 387 | 5.8 | 0.70 | 1,219 | 831 | 68 |
| | | **Total** | 6,642 | 100 | 1.51 | 18,054 | 11,412 | 63 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Cultivated cropland acres used in HUMUS/SWAT modeling vary slightly from acre estimates based on the CEAP sample. Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 23.** Average annual sediment loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | | | | Reductions in loads due to conservation practices | |
|---|---|---|---|---|---|---|---|---|
| 8-digit HUC group* | Sub-basin code | Subbasin name | Amount (1,000 tons) | Percent of basin total | Tons delivered per cropland acre | No-practice Scenario (1,000 tons) | Reduction (1,000 tons) | Percent |
| I | 0205 | Susquehanna River | 1,696 | 71 | 0.84 | 4,201 | 2,504 | 60 |
| II | 0206 | Upper Chesapeake** | 265 | 11 | 0.22 | 1,014 | 749 | 74 |
| III | 0207 | Potomac River | 266 | 11 | 0.43 | 927 | 662 | 71 |
| IV + V | 0208 | Lower Chesapeake** | 155 | 6 | 0.28 | 492 | 337 | 69 |
| | | **Total** | 2,381 | 100 | 0.54 | 6,634 | 4,252 | 64 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 22 are due to the application of delivery ratios, which were used to simulate delivery of sediment from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 24.** Average annual sediment loads ***delivered to watershed outlets*** (8-digit HUCs***) from all sources*** for the 4 subbasins in the Chesapeake Bay watershed

| 8-digit HUC group | Sub-basin code | Subbasin name | All sources | Cultivated cropland* | Hayland | Pasture and grazing land | Urban: Non-point sources** | Urban: Point sources | Forest and other*** |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *Amount (1,000 tons)* | | | |
| I | 0205 | Susquehanna River | 4,513 | 1,696 | 708 | 139 | 1,274 | 0 | 696 |
| II | 0206 | Upper Chesapeake**** | 1,166 | 265 | 7 | 79 | 473 | 0 | 342 |
| III | 0207 | Potomac River | 2,080 | 266 | 139 | 147 | 1,083 | 0 | 445 |
| IV + V | 0208 | Lower Chesapeake**** | 1,807 | 155 | 69 | 178 | 787 | 0 | 619 |
| | | **Total** | 9,567 | 2,381 | 924 | 543 | 3,617 | 0 | 2,102 |
| | | | | | | *Percent of all sources* | | | |
| I | 0205 | Susquehanna River | 100 | 38 | 16 | 3 | 28 | 0 | 15 |
| II | 0206 | Upper Chesapeake**** | 100 | 23 | 1 | 7 | 41 | 0 | 29 |
| III | 0207 | Potomac River | 100 | 13 | 7 | 7 | 52 | 0 | 21 |
| IV + V | 0208 | Lower Chesapeake**** | 100 | 9 | 4 | 10 | 44 | 0 | 34 |
| | | **Total** | 100 | 25 | 10 | 6 | 38 | 0 | 22 |

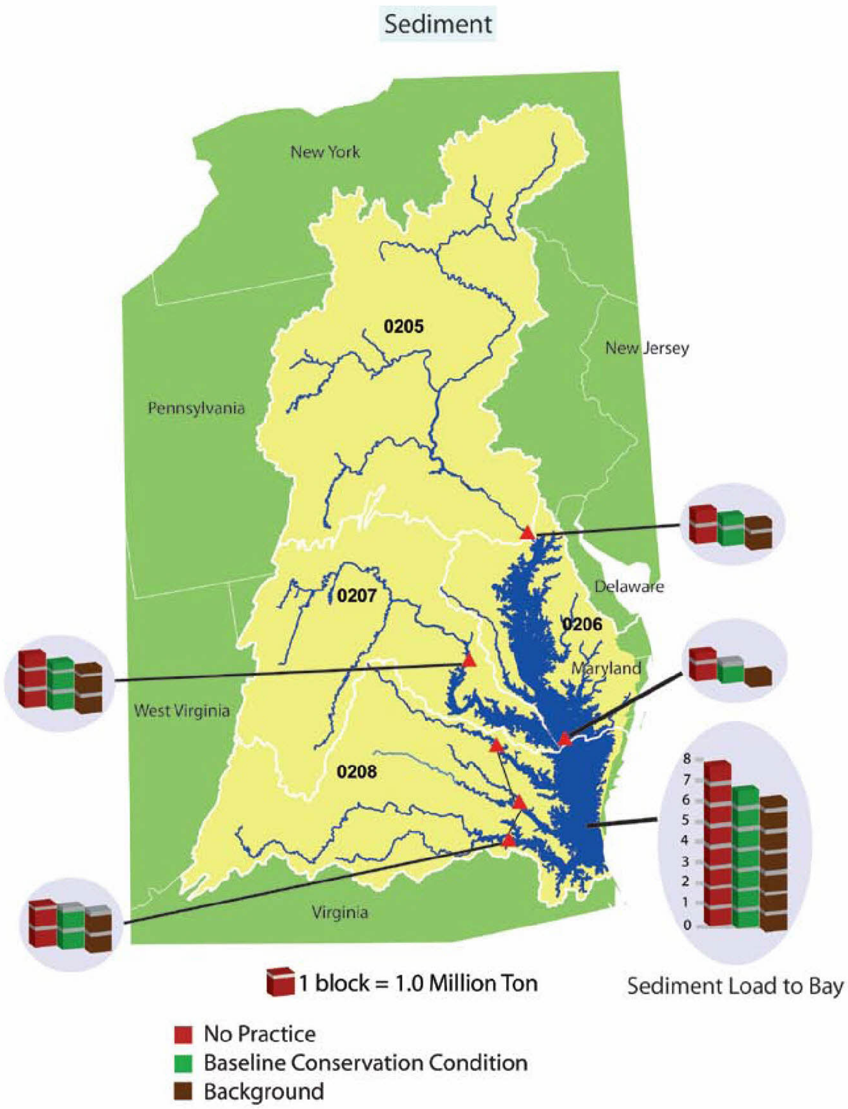
* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, range brush, horticulture, and barren land.
****Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 25.** Average annual ***instream sediment loads*** delivered to the Chesapeake Bay

| Subbasin name | Sub-basin code | 8-digit HUC group* | Baseline conservation condition: Load from all sources (1,000 tons) | Baseline conservation condition: Background sources** (1,000 tons) | Baseline conservation condition: Percent of load attributed to cultivated cropland sources | No-practice scenario (1,000 tons) | Reductions in loads due to conservation practices: Reduction (1,000 tons) | Reductions in loads due to conservation practices: Percent |
|---|---|---|---|---|---|---|---|---|
| Upper Chesapeake Bay | | | | | | | | |
| Susquehanna River | 0205 | I | 1,441 | 1,294 | 10 | 1,592 | 151 | 9 |
| Upper Chesapeake | 0206 | II | 952 | 795 | 16 | 1,378 | 425 | 31 |
| Potomac River | 0207 | III | 2,392 | 2,256 | 6 | 2,742 | 349 | 13 |
| **Sub-total** | | | 4,785 | 4,345 | 9 | 5,711 | 926 | 16 |
| Lower Chesapeake Bay | | | | | | | | |
| Rappahannock, York, and James Rivers | 0208 | IV | 2,034 | 1,962 | 4 | 2,201 | 167 | 8 |
| Eastern Shore | 0208 | V | 36 | 31 | 14 | 42 | 6.2 | 15 |
| **Sub-total** | | | 2,070 | 1,993 | 4 | 2,243 | 173 | 8 |
| **Total** | | | 6,855 | 6,338 | 8 | 7,954 | 1,099 | 14 |

*See figure 54.
** "Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

**Figure 56**. Estimates of average annual instream sediment loads for the baseline conservation condition compared to the no-practice scenario for subbasins in the Chesapeake Bay watershed*




* Instream sediment loads delivered to the Chesapeake Bay (all sources) are shown for each of the four subbasins, corresponding to estimates presented in table 25. The total sediment load delivered to the Chesapeake Bay from all areas is shown in the bar chart in the lower right hand corner, labeled "Sediment load to Bay."

**Note**: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

## Total Nitrogen

Proportionally, total nitrogen loads (all forms) from cultivated cropland are higher than sediment or phosphorus loads. Model simulation results show that about 158 million pounds of nitrogen are lost from farm fields (edge-of-field) through pathways that result in delivery to streams and rivers within the Chesapeake Bay watershed (table 26). Of this, about 107 million pounds is delivered into rivers and streams each year, on average, under conditions represented by the baseline conservation condition (table 27), which include farming activities and conservation practices in use during 2003-2006. The majority (about 59 percent) of the nitrogen from cultivated cropland originates in the Susquehanna River subbasin, as is the case for sediment and phosphorus. Nitrogen delivered to rivers and streams from cultivated cropland represents about 32 percent of the total nitrogen load delivered from all sources (table 28, figure 57). Runoff from urban land, including point sources, delivers slightly more nitrogen—about 37 percent of the total load delivered to streams and rivers.

Instream loads—the amount of nitrogen delivered to the Bay after accounting for denitrification, deposition and other instream transport processes—totals about 314 million pounds from all sources, averaged over the 47 years of weather as simulated in the model (table 29, figure 58). Overall, about 30 percent of these instream loads delivered to the Bay are attributable to cultivated cropland sources.

Instream loads from all sources delivered to the Bay were greatest for the Susquehanna River subbasin (figure 58). The Susquehanna River also has the highest proportion of instream loads attributable to cultivated cropland—43 percent.

Conservation practices in use throughout the watershed have reduced nitrogen loads, but not as dramatically as sediment loads, as discussed in the previous chapter. Model simulations indicate that conservation practices have reduced the delivery of nitrogen from fields to rivers and streams by about 36 percent (table 27), on average, and reduced delivery of nitrogen to the Bay by about 15 percent (table 29, figure 58). Nitrogen loads delivered to the Bay would have been larger by about 57 million pounds per year if conservation practices were not in use (table 29). Over half of this reduction is in the Susquehanna River subbasin, where total nitrogen instream loads have been reduced by 20 percent due to the use of conservation practices.

**Figure 57**. Percentage by source of average annual nitrogen loads delivered to rivers and streams in the Chesapeake Bay watershed

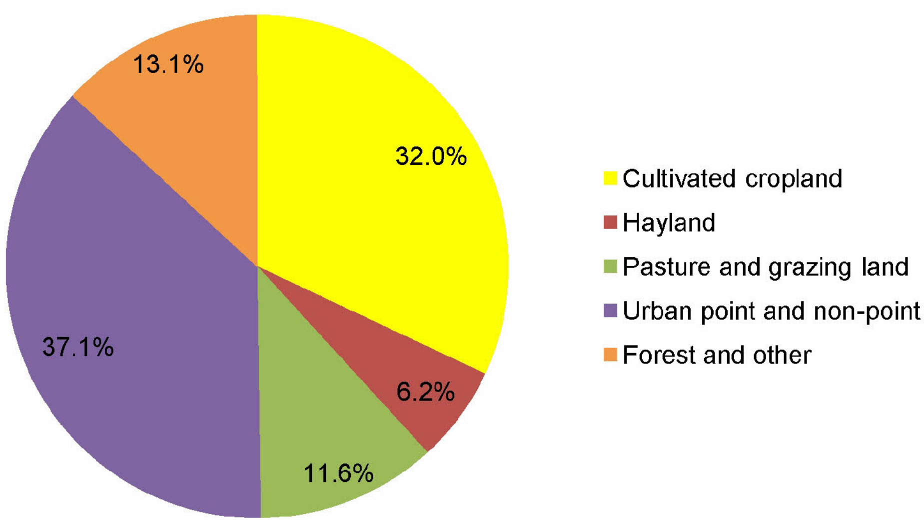


**Table 26.** Average annual nitrogen source loads ***delivered to edge of field*** (APEX model output) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | | | | Reductions in loads due to conservation practices | |
|---|---|---|---|---|---|---|---|---|
| 8-digit HUC group* | Sub-basin code | Subbasin name | Amount (1,000 pounds) | Percent of basin total | Pounds delivered per cropland acre | No-practice Scenario (1,000 pounds) | Reduction (1,000 pounds) | Percent |
| I | 0205 | Susquehanna River | 93,143 | 59 | 46.40 | 148,190 | 55,050 | 37 |
| II | 0206 | Upper Chesapeake** | 33,504 | 21 | 27.50 | 52,232 | 18,728 | 36 |
| III | 0207 | Potomac River | 20,013 | 13 | 32.74 | 33,159 | 13,146 | 40 |
| IV + V | 0208 | Lower Chesapeake** | 11,464 | 7.3 | 20.71 | 18,125 | 6,661 | 37 |
| | | **Total** | 158,120 | 100 | 36.01 | 251,710 | 93,585 | 37 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Cultivated cropland acres used in HUMUS/SWAT modeling vary slightly from acre estimates based on the CEAP sample. Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 27.** Average annual nitrogen source loads ***delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | | | | Reductions in loads due to conservation practices | |
|---|---|---|---|---|---|---|---|---|
| 8-digit HUC group* | Sub-basin code | Subbasin name | Amount (1,000 pounds) | Percent of basin total | Pounds delivered per cropland acre | No-practice Scenario (1,000 pounds) | Reduction (1,000 pounds) | Percent |
| I | 0205 | Susquehanna River | 61,598 | 57 | 30.7 | 96,960 | 35,362 | 36 |
| II | 0206 | Upper Chesapeake** | 24,156 | 23 | 19.8 | 37,134 | 12,978 | 35 |
| III | 0207 | Potomac River | 13,513 | 13 | 22.1 | 22,018 | 8,505 | 39 |
| IV + V | 0208 | Lower Chesapeake** | 7,992 | 7 | 14.4 | 12,756 | 4,764 | 37 |
| | | **Total** | 107,260 | 100 | 24.4 | 168,870 | 61,609 | 36 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 26 are due to the application of delivery ratios, which were used to simulate delivery of nitrogen from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 28.** Average annual nitrogen loads ***delivered to watershed outlets*** (8-digit HUCs***) from all sources*** for the 4 subbasins in the Chesapeake Bay watershed

| 8-digit HUC group | Sub-basin code | Subbasin name | All sources | Cultivated cropland* | Hayland | Pasture and grazing land | Urban: Non-point sources** | Urban: Point sources | Forest and other*** |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *Amount (1,000 pounds)* | | | |
| I | 0205 | Susquehanna River | 143,459 | 61,609 | 13,891 | 15,821 | 9,334 | 24,760 | 18,045 |
| II | 0206 | Upper Chesapeake**** | 54,676 | 24,160 | 543 | 4,111 | 5,047 | 16,419 | 4,397 |
| III | 0207 | Potomac River | 79,007 | 13,515 | 4,457 | 12,601 | 9,743 | 28,250 | 10,441 |
| IV + V | 0208 | Lower Chesapeake**** | 58,000 | 7,994 | 1,856 | 6,302 | 6,840 | 23,916 | 11,091 |
| | | **Total** | 335,142 | 107,277 | 20,747 | 38,835 | 30,964 | 93,345 | 43,974 |
| | | | | | | *Percent of all sources* | | | |
| I | 0205 | Susquehanna River | 100 | 43 | 10 | 11 | 7 | 17 | 13 |
| II | 0206 | Upper Chesapeake**** | 100 | 44 | 1 | 8 | 9 | 30 | 8 |
| III | 0207 | Potomac River | 100 | 17 | 6 | 16 | 12 | 36 | 13 |
| IV + V | 0208 | Lower Chesapeake**** | 100 | 14 | 3 | 11 | 12 | 41 | 19 |
| | | **Total** | 100 | 32 | 6 | 12 | 9 | 28 | 13 |

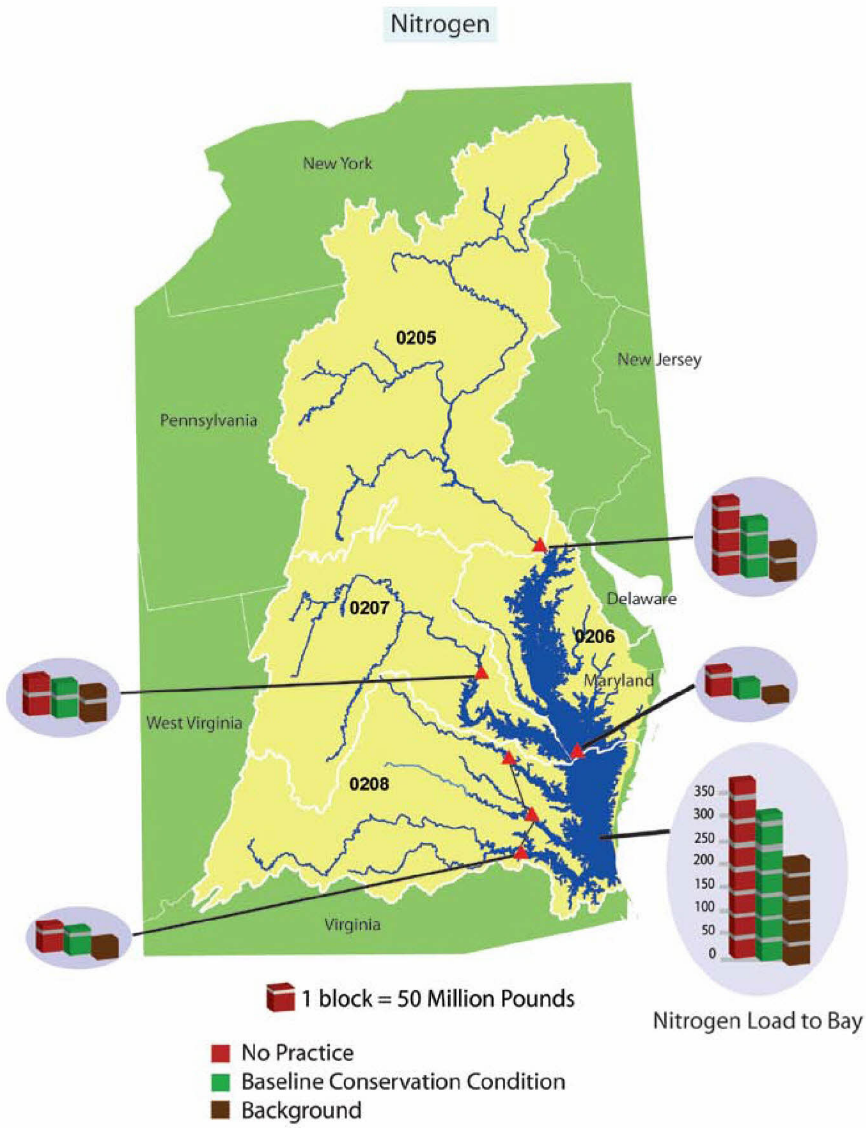
* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, range brush, horticulture, and barren land.
****Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 29.** Average annual ***instream nitrogen loads*** delivered to the Chesapeake Bay

| Subbasin name | Sub-basin code | 8-digit HUC group* | Baseline conservation condition: Load from all sources (1,000 pounds) | Baseline conservation condition: Background sources** (1,000 pounds) | Baseline conservation condition: Percent of load attributed to cultivated cropland sources | No-practice scenario (1,000 pounds) | Reductions in loads due to conservation practices: Reduction (1,000 pounds) | Reductions in loads due to conservation practices: Percent |
|---|---|---|---|---|---|---|---|---|
| Upper Chesapeake Bay | | | | | | | | |
| Susquehanna River | 0205 | I | 128,280 | 73,661 | 43 | 160,580 | 32,307 | 20 |
| Upper Chesapeake | 0206 | II | 47,853 | 29,281 | 39 | 58,889 | 11,037 | 19 |
| Potomac River | 0207 | III | 81,261 | 67,442 | 17 | 90,096 | 8,835 | 10 |
| **Sub-total** | | | 257,394 | 170,384 | 34 | 309,565 | 52,179 | 17 |
| Lower Chesapeake Bay | | | | | | | | |
| Rappahannock, York, and James Rivers | 0208 | IV | 55,195 | 48,488 | 12 | 59,311 | 4,116 | 7 |
| Eastern Shore | 0208 | V | 1,443 | 856 | 41 | 1,820 | 378 | 21 |
| **Sub-total** | | | 56,638 | 49,344 | 13 | 61,131 | 4,494 | 7 |
| **Total** | | | 314,032 | 219,728 | 30 | 370,696 | 56,673 | 15 |

*See figure 54.
** "Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

**Figure 58**. Estimates of average annual instream nitrogen loads for the baseline conservation condition compared to the no-practice scenario for subbasins in the Chesapeake Bay watershed*




* Instream nitrogen loads delivered to the Chesapeake Bay (all sources) are shown for each of the four subbasins, corresponding to estimates presented in table 29. The total sediment load delivered to the Chesapeake Bay from all areas is shown in the bar chart in the lower right hand corner, labeled "Nitrogen load to Bay."

**Note**: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

## Total Phosphorus

Model simulation results show that about 16 million pounds of phosphorus are lost from farm fields (edge-of-field) through pathways that result in delivery to streams and rivers within the Chesapeake Bay watershed (table 30). Of this, about 6.2 million pounds is delivered into rivers and streams each year, on average, under conditions represented by the baseline conservation condition (table 31), which include farming activities and conservation practices in use during 2003-2006. The majority of the phosphorus from cultivated cropland originates in the Susquehanna River subbasin. Phosphorus delivered to rivers and streams from cultivated cropland represents about 28 percent of the total phosphorus load delivered from all sources (table 32, figure 59). The dominant source of phosphorus delivered into streams and rivers is runoff from urban land and point sources—about 51 percent of the total load delivered to streams and rivers.

Instream loads—the amount of phosphorus delivered to the Bay after accounting for deposition and other instream transport processes—totals about 15 million pounds from all sources, averaged over the 47 years of weather as simulated in the model (table 33, figure 60). Overall, about 24 percent of these instream loads delivered to the Bay are attributable to cultivated cropland sources.

Instream loads from all sources delivered to the Bay were greatest for the Lower Chesapeake subbasin (figure 60), mostly from sources other than cultivated cropland. The Susquehanna River and the Upper Chesapeake subbasins have the highest proportion of instream loads attributable to cultivated cropland—34 percent (table 33).

Phosphorus loads delivered to streams and rivers would have been much larger if soil erosion control practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of phosphorus from fields to rivers and streams by about 43 percent (table 31), on average, and reduced delivery of phosphorus to the Bay by about 15 percent (table 33, figure 60). Phosphorus loads delivered to the Bay would have been larger by about 2.6 million pounds per year if conservation practices were not in use (table 33). The Upper Chesapeaake subbasin has the highest percent reduction in instream loads delivered to the Bay due to conservation practices—30 percent.

**Figure 59**. Percentage by source of average annual phosphorus loads delivered to rivers and streams in the Chesapeake Bay watershed

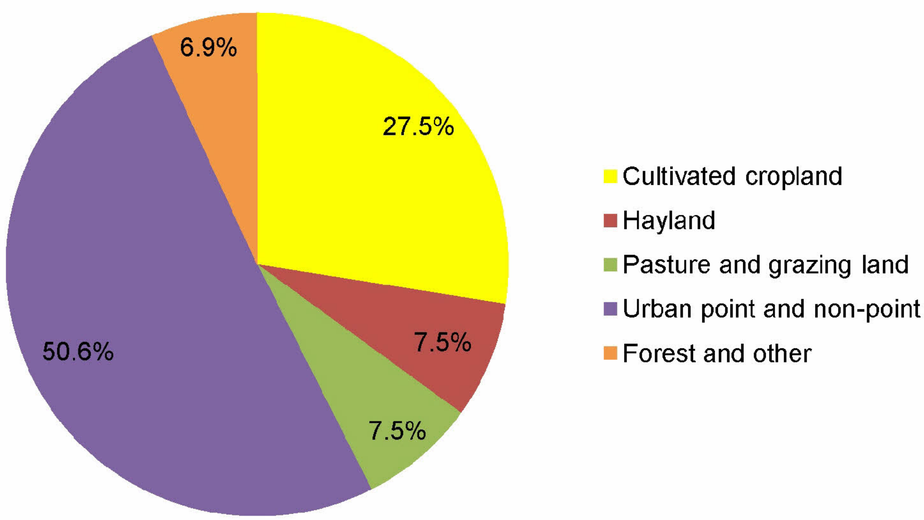


**Table 30.** Average annual phosphorus source loads ***delivered to edge of field*** (APEX model output) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| 8-digit HUC group* | Sub-basin code | Subbasin name | Baseline conservation condition: Amount (1,000 pounds) | Percent of basin total | Pounds delivered per cropland acre | No-practice Scenario (1,000 pounds) | Reductions in loads due to conservation practices: Reduction (1,000 pounds) | Percent |
|---|---|---|---|---|---|---|---|---|
| I | 0205 | Susquehanna River | 9,883 | 60 | 4.92 | 17,939 | 8,056 | 45 |
| II | 0206 | Upper Chesapeake** | 2,306 | 14 | 1.89 | 5,138 | 2,832 | 55 |
| III | 0207 | Potomac River | 2,989 | 18 | 4.89 | 4,998 | 2,009 | 40 |
| IV + V | 0208 | Lower Chesapeake** | 1,223 | 7.5 | 2.21 | 1,930 | 707 | 37 |
| | | **Total** | 16,400 | 100 | 3.74 | 30,004 | 13,604 | 45 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Cultivated cropland acres used in HUMUS/SWAT modeling vary slightly from acre estimates based on the CEAP sample. Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 31.** Average annual phosphorus source loads ***delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| 8-digit HUC group* | Sub-basin code | Subbasin name | Baseline conservation condition: Amount (1,000 pounds) | Percent of basin total | Pounds delivered per cropland acre | No-practice Scenario (1,000 pounds) | Reductions in loads due to conservation practices: Reduction (1,000 pounds) | Percent |
|---|---|---|---|---|---|---|---|---|
| I | 0205 | Susquehanna River | 3,529 | 57 | 1.76 | 6,147 | 2,618 | 43 |
| II | 0206 | Upper Chesapeake** | 973 | 16 | 0.80 | 2,103 | 1,129 | 54 |
| III | 0207 | Potomac River | 1,181 | 19 | 1.93 | 1,814 | 634 | 35 |
| IV + V | 0208 | Lower Chesapeake** | 511 | 8 | 0.92 | 775 | 264 | 34 |
| | | **Total** | 6,193 | 100 | 1.41 | 10,838 | 4,645 | 43 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 30 are due to the application of delivery ratios, which were used to simulate delivery of phosphorus from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 32.** Average annual phosphorus loads ***delivered to watershed outlets*** (8-digit HUCs***) from all sources*** for the 4 subbasins in the Chesapeake Bay watershed

| 8-digit HUC group | Sub-basin code | Subbasin name | All sources | Cultivated cropland* | Hayland | Pasture and grazing land | Urban: Non-point sources** | Urban: Point sources | Forest and other*** |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *Amount (1,000 pounds)* | | | |
| I | 0205 | Susquehanna River | 10,426 | 3,529 | 1,316 | 554 | 580 | 3,885 | 562 |
| II | 0206 | Upper Chesapeake**** | 2,546 | 973 | 15 | 132 | 198 | 1,015 | 214 |
| III | 0207 | Potomac River | 4,820 | 1,181 | 270 | 602 | 531 | 1,895 | 341 |
| IV + V | 0208 | Lower Chesapeake**** | 4,727 | 511 | 87 | 406 | 417 | 2,870 | 436 |
| | | **Total** | 22,519 | 6,194 | 1,689 | 1,693 | 1,726 | 9,664 | 1,552 |
| | | | | | | *Percent of all sources* | | | |
| I | 0205 | Susquehanna River | 100 | 34 | 13 | 5 | 6 | 37 | 5 |
| II | 0206 | Upper Chesapeake**** | 100 | 38 | 1 | 5 | 8 | 40 | 8 |
| III | 0207 | Potomac River | 100 | 24 | 6 | 12 | 11 | 39 | 7 |
| IV + V | 0208 | Lower Chesapeake**** | 100 | 11 | 2 | 9 | 9 | 61 | 9 |
| | | **Total** | 100 | 28 | 7 | 8 | 8 | 43 | 7 |

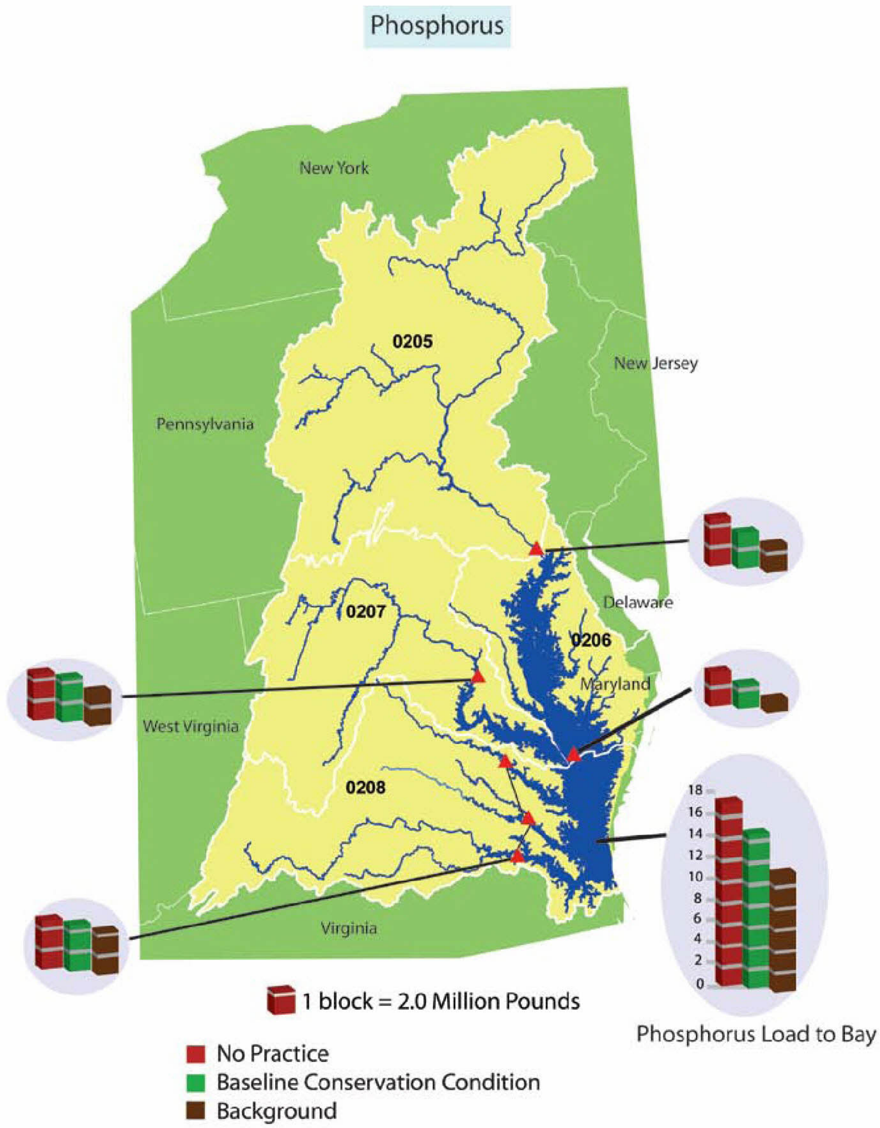
* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, range brush, horticulture, and barren land.
****Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 33.** Average annual ***instream phosphorus loads*** delivered to the Chesapeake Bay

| Subbasin name | Sub-basin code | 8-digit HUC group* | Baseline conservation condition: Load from all sources (1,000 pounds) | Baseline conservation condition: Background sources** (1,000 pounds) | Baseline conservation condition: Percent of load attributed to cultivated cropland sources | No-practice scenario (1,000 pounds) | Reductions in loads due to conservation practices: Reduction (1,000 pounds) | Reductions in loads due to conservation practices: Percent |
|---|---|---|---|---|---|---|---|---|
| Upper Chesapeake Bay | | | | | | | | |
| Susquehanna River | 0205 | I | 3,803 | 2,500 | 34 | 4,752 | 948 | 20 |
| Upper Chesapeake | 0206 | II | 2,234 | 1,467 | 34 | 3,175 | 941 | 30 |
| Potomac River | 0207 | III | 4,068 | 3,074 | 24 | 4,589 | 521 | 11 |
| **Sub-total** | | | 10,105 | 7,041 | 30 | 12,516 | 2,410 | 19 |
| Lower Chesapeake Bay | | | | | | | | |
| Rappahannock, York, and James Rivers | 0208 | IV | 4,557 | 4,117 | 10 | 4,765 | 208 | 4 |
| Eastern Shore | 0208 | V | 87 | 72 | 17 | 115 | 27 | 24 |
| **Sub-total** | | | 4,644 | 4,189 | 10 | 4,880 | 236 | 5 |
| **Total** | | | 14,749 | 11,229 | 24 | 17,395 | 2,646 | 15 |

*See figure 54.
** “Background sources” represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

**Figure 60**. Estimates of average annual instream phosphorus loads for the baseline conservation condition compared to the no-practice scenario for subbasins in the Chesapeake Bay watershed*




* Instream phosphorus loads delivered to the Chesapeake Bay (all sources) are shown for each of the four subbasins, corresponding to estimates presented in table 33. The total sediment load delivered to the Chesapeake Bay from all areas is shown in the bar chart in the lower right hand corner, labeled "Phosphorus load to Bay."

**Note**: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

## Atrazine

Although the full suite of pesticides were modeled for edge-of-field losses, atrazine was the only pesticide for which in-stream loads were assessed because it was the dominant contributor to mass loss of pesticide residues from farm fields and the primary contributor to environmental risk from pesticides in the region. First registered in the United States in 1959, atrazine is used to control broadleaf and grassy weeds.

Cultivated cropland (primarily corn acres) was the only source for atrazine in the model simulations.

Model simulation results show that about 15 thousand pounds of atrazine are lost from farm fields (edge-of-field) through pathways that result in delivery to streams and rivers within the Chesapeake Bay watershed (table 34). Of this, about 13 thousand pounds is delivered into rivers and streams each year, on average, under conditions represented by the baseline conservation condition (table 35). About half of the atrazine from cultivated cropland originates in the Susquehanna River subbasin. Instream loads—the amount of atrazine delivered to the Bay after accounting for degradation and other instream transport processes—totals about 9 thousand pounds (table 36).

Conservation practices—including Integrated Pest Management (IPM) techniques and practices—have reduced the delivery of atrazine from fields to rivers and streams by about 31 percent (table 35), on average, and reduced delivery of atrazine to the Bay by about 26 percent (table 36, figure 61). Atrazine loads delivered to the Bay would have been larger by about 3.2 thousand pounds per year if conservation practices were not in use (table 36).

**Table 34.** Average annual atrazine source loads ***delivered to edge of field*** (APEX model output) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | | | | Reductions in loads due to conservation practices | |
|---|---|---|---|---|---|---|---|---|
| 8-digit HUC group* | Sub-basin code | Subbasin name | Amount (1,000 pounds) | Percent of basin total | Pounds delivered per cropland acre | No-practice Scenario (1,000 pounds) | Reduction (1,000 pounds) | Percent |
| I | 0205 | Susquehanna River | 7.2 | 48 | 0.0036 | 10.5 | 3.3 | 31 |
| II | 0206 | Upper Chesapeake** | 4.1 | 27 | 0.0033 | 6.7 | 2.6 | 39 |
| III | 0207 | Potomac River | 2.5 | 17 | 0.0041 | 3.0 | 0.5 | 18 |
| IV + V | 0208 | Lower Chesapeake** | 1.2 | 8 | 0.0021 | 1.4 | 0.2 | 14 |
| | | **Total** | 14.9 | 100 | 0.0034 | 21.6 | 6.6 | 31 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Cultivated cropland acres used in HUMUS/SWAT modeling vary slightly from acre estimates based on the CEAP sample. Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 35.** Average annual atrazine source loads ***delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | | | | Reductions in loads due to conservation practices | |
|---|---|---|---|---|---|---|---|---|
| 8-digit HUC group* | Sub-basin code | Subbasin name | Amount (1,000 pounds) | Percent of basin total | Pounds delivered per cropland acre | No-practice Scenario (1,000 pounds) | Reduction (1,000 pounds) | Percent |
| I | 0205 | Susquehanna River | 6.3 | 48 | 0.0031 | 9.1 | 2.8 | 31 |
| II | 0206 | Upper Chesapeake** | 3.7 | 28 | 0.0030 | 6.1 | 2.5 | 40 |
| III | 0207 | Potomac River | 2.2 | 17 | 0.0036 | 2.6 | 0.4 | 17 |
| IV + V | 0208 | Lower Chesapeake** | 1.0 | 8 | 0.0018 | 1.1 | 0.2 | 14 |
| | | **Total** | 13.1 | 100 | 0.0030 | 19.0 | 5.9 | 31 |

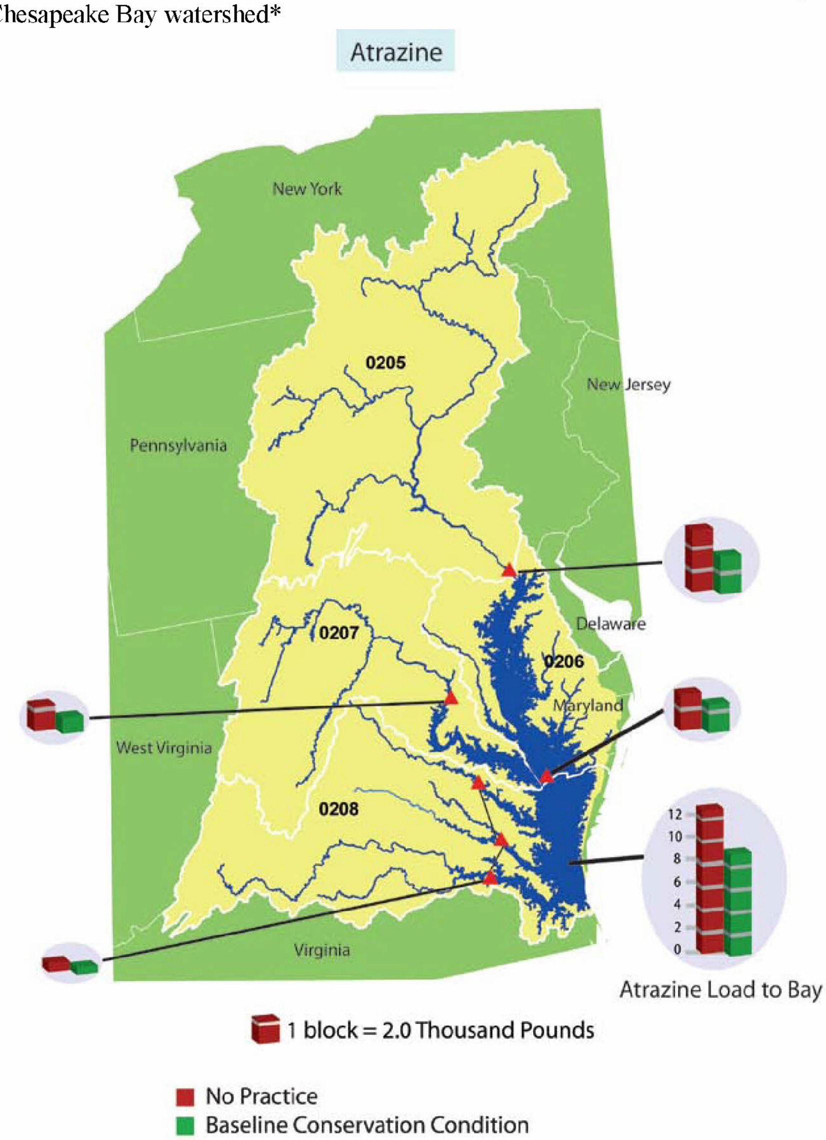
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 34 are due to the application of delivery ratios, which were used to simulate delivery of atrazine from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 36.** Average annual ***instream atrazine loads*** delivered to the Chesapeake Bay

| | | | | | Reductions in loads due to conservation practices | |
|---|---|---|---|---|---|---|
| Subbasin name | Sub-basin code | 8-digit HUC group* | Baseline conservation condition (1,000 pounds) | No-practice scenario (1,000 pounds) | Reduction (1,000 pounds) | Percent |
| Upper Chesapeake Bay | | | | | | |
| Susquehanna River | 0205 | I | 3.86 | 5.59 | 1.73 | 31 |
| Upper Chesapeake | 0206 | II | 2.49 | 3.46 | 0.97 | 28 |
| Potomac River | 0207 | III | 1.86 | 2.19 | 0.33 | 15 |
| **Sub-total** | | | 8.20 | 11.24 | 3.04 | 27 |
| Lower Chesapeake Bay | | | | | | |
| Rappahannock, York, and James Rivers | 0208 | IV | 0.82 | 0.96 | 0.14 | 15 |
| Eastern Shore | 0208 | V | 0.04 | 0.05 | 0.01 | 24 |
| **Sub-total** | | | 0.86 | 1.01 | 0.15 | 15 |
| **Total** | | | 9.06 | 12.25 | 3.19 | 26 |

*See figure 54.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

**Figure 61**. Estimates of average annual instream atrazine loads for the baseline conservation condition compared to the no-practice scenario for subbasins in the Chesapeake Bay watershed*




* Instream atrazine loads delivered to the Chesapeake Bay (all sources) are shown for each of the four subbasins, corresponding to estimates presented in table 36. The total sediment load delivered to the Chesapeake Bay from all areas is shown in the bar chart in the lower right hand corner, labeled "Atrazine load to Bay."

# Chapter 6 Assessment of Conservation Treatment Needs

The adequacy of the conservation practices in use in the Chesapeake Bay region was evaluated to identify remaining conservation treatment needs for controlling sediment and nutrient loss. Field-level results for the baseline conservation conditions were used to make the assessment. Adequate conservation treatment consists of combinations of conservation practices that treat the specific inherent vulnerability factors associated with each field. Four resource concerns were evaluated:

1. Sediment loss due to water erosion
2. Nitrogen lost to surface water (nitrogen attached to sediment and in solution)
3. Nitrogen loss in subsurface flows
4. Phosphorus lost to surface water (phosphorus attached to sediment and in solution)

The assessment showed that the suite of practices in use in the Chesapeake Bay region was often inadequate to address all four resource concerns simultaneously.

The conservation treatment needs for controlling pesticide loss were not evaluated because it requires information on pest infestations, which was not available for the CEAP sample points. A portion of the pesticide residues are controlled by soil erosion control practices; meeting soil erosion control treatment needs would provide partial protection against loss of pesticide residues from farm fields. Integrated Pest Management (IPM) practices are also effective in reducing the risk associated with pesticide residues leaving the farm field. Determination of adequate IPM, however, is highly dependent on the specific site conditions and the nature and extent of the pest problems.

## Conservation Treatment Levels

Four levels of conservation treatment (high, moderately high, moderate, and low) were defined as combinations of conservation practices for controlling (1) sediment loss due to water erosion, (2) nitrogen lost to surface water, and (3) phosphorus lost to surface water. Criteria for these management levels are presented in figures 62, 63, and 64, along with results on the extent to which these management levels are represented in the Chesapeake Bay region. The nitrogen management level presented in figure 12 was used to evaluate the adequacy of conservation treatment for nitrogen loss in subsurface flows.

A "high" level of treatment was shown by model simulations to reduce sediment and nutrient losses to acceptable levels for nearly all cropped acres in the Chesapeake Bay region. Key findings are:

- A high level of water erosion control treatment (combination of structural practices and residue and tillage management practices) is in use on about 16 percent of cropped acres (figure 62), primarily on non-highly erodible land. Only 3 percent of the highly erodible acres have a high level of treatment. About 21 percent of the highly erodible acres have a moderately high level of water erosion control treatment.
- A high level of treatment for nitrogen runoff (combination of structural practices, residue and tillage management practices, and nitrogen management practices) is in use on less than 1 percent of the acres (figure 63). About 22 percent of the acres have combinations of practices that indicate a moderately high level of treatment.
- A high level of treatment for phosphorus runoff is in use on only 3 percent of the acres (figure 64). About 22 percent of the acres have a moderately high level of treatment for controlling phosphorus loss with surface runoff.

## Inherent Vulnerability Factors

Not all acres require the same level of conservation treatment because of differences in inherent vulnerabilities. Inherent vulnerability factors for surface runoff include soil properties that promote surface water runoff and erosion. Inherent vulnerability factors for loss of nutrients in subsurface flows include soil properties that promote infiltration.

Soil runoff and leaching potentials were estimated for each sample point on the basis of vulnerability criteria presented in figures 65 and 66. A single set of criteria were developed for all regions and soils in the US to allow for regional comparisons. Thus, some soil runoff and leaching potentials are not well represented in every region. The spatial distribution of the soil runoff and leaching potentials within the Chesapeake Bay region are presented in figures 67 and 68. The maps show the soil potentials for all soils and land uses in the region. For the assessment of conservation treatment needs, however, only the soil potentials for cropped acres were used.

Cropped acres in the Chesapeake Bay region are a mix of vulnerable and non-vulnerable acres. About 47 percent of cropped acres in the Chesapeake Bay region have a low soil runoff potential (figure 65). However, 23 percent of the acres have a high soil runoff potential, consisting almost entirely of highly erodible land, and 19 percent have a moderately high soil runoff potential.

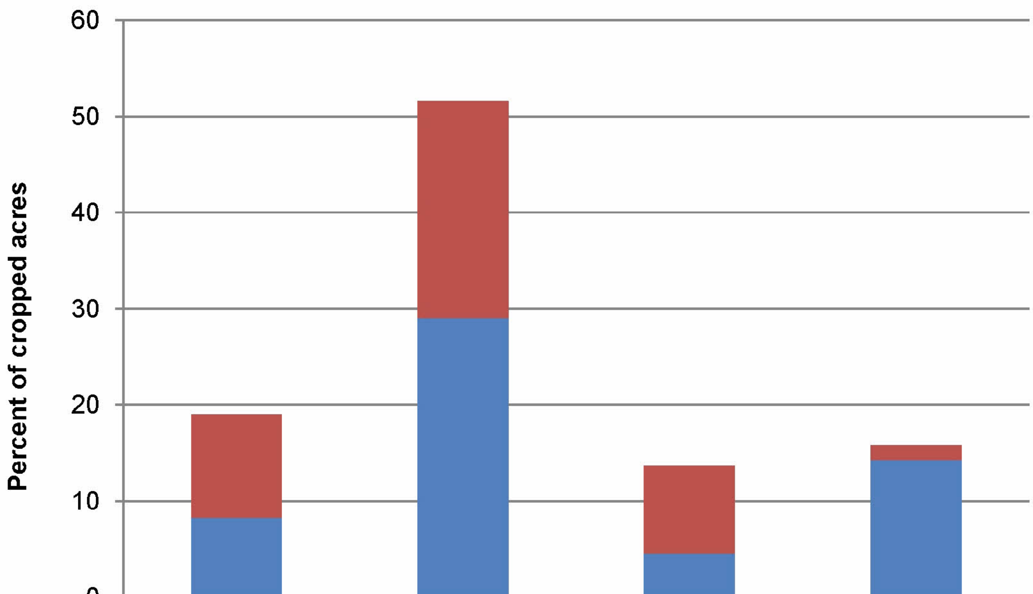
About 17 percent of the cropped acres have a high soil leaching potential (figure 66). About 29 percent have a moderately high soil leaching potential and 48 percent have a moderate soil leaching potential. About 6 percent of cropped acres have a low soil leaching potential in this region.

Estimates of sediment and nutrient losses for the no-practice scenario (without conservation practices) demonstrate how vulnerability factors influence losses in the Chesapeake Bay region:

- Sediment loss for the low soil runoff potential averaged 1.1 tons per acre per year, compared to 9.5 tons per acre per year for the high soil runoff potential.

- Nitrogen lost to surface water for the low soil runoff potential averaged 6 pounds per acre per year, compared to 37 pounds per acre per year for the high soil runoff potential.
- Nitrogen loss in subsurface flows for the low soil leaching potential averaged 33 pounds per acre per year, compared to 66 pounds per acre per year for the high soil leaching potential.
- Phosphorus lost to surface water for the low soil runoff potential averaged 3.6 pounds per acre per year, compared to 11.3 pounds per acre per year for the high soil runoff potential.

**Figure 62**. Conservation treatment levels for water erosion control in the baseline conservation condition, Chesapeake Bay region



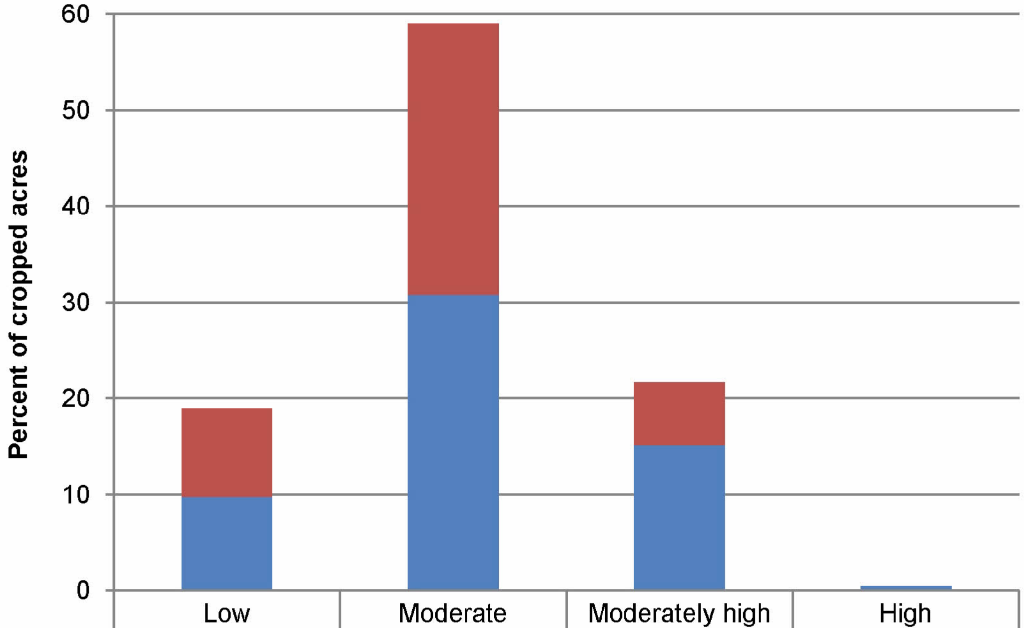

| | Low | Moderate | Moderately high | High |
|---|---|---|---|---|
| HEL | 10.7 | 22.5 | 9.1 | 1.5 |
| Non-HEL | 8.3 | 29.0 | 4.5 | 14.3 |

Criteria for water erosion control treatment levels were derived using a combination of structural practice treatment levels and residue and tillage management treatment levels (see figures 10 and 11). Scores were first assigned to these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1. If slope was 2 percent or less, the water erosion control treatment level is the same as the residue and tillage management level. If slope was greater than 2 percent, the water erosion control treatment level is determined as follows:

- **High treatment**: Sum of scores is equal to 8. (High treatment level for both structural practices and residue and tillage management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

Note: About 44 percent of cropped acres in the Chesapeake Bay region is highly erodible land.

**Figure 63**. Conservation treatment levels for nitrogen runoff control in the baseline conservation condition, Chesapeake Bay region




| | Low | Moderate | Moderately high | High |
|---|---|---|---|---|
| HEL | 9.2 | 28.2 | 6.5 | 0.0 |
| Non-HEL | 9.8 | 30.8 | 15.1 | 0.4 |

Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and nitrogen management treatment levels (see figures 10-12). Scores were first assigned to these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1.

If slope was 2 percent or less, the nitrogen runoff control treatment level is determined as follows:

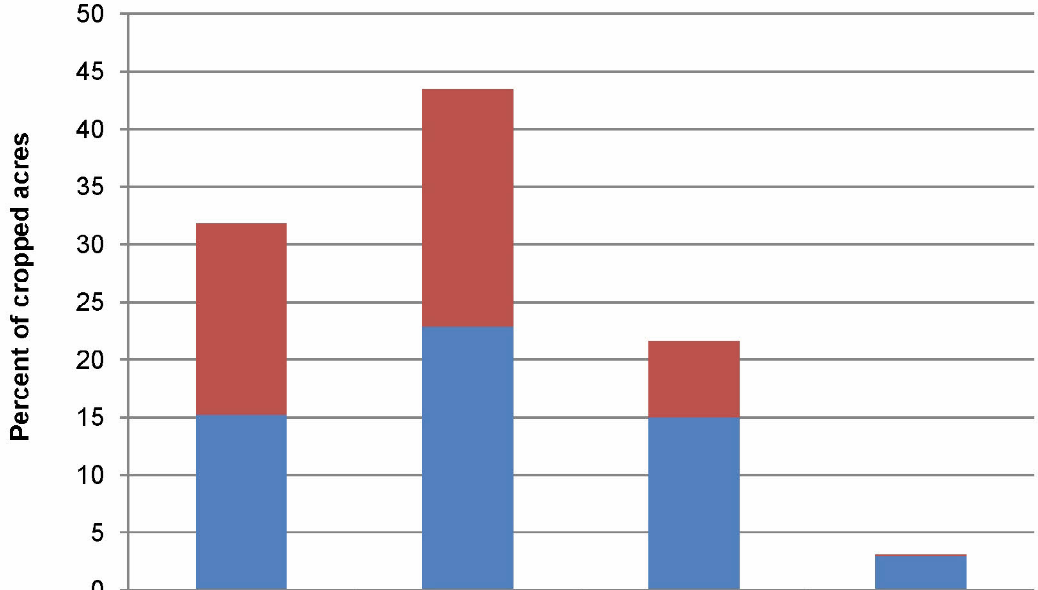
- **High treatment**: Sum of residue and tillage management score and nitrogen management score is equal to 8. (High treatment level for both structural practices and nitrogen management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

If slope was greater than 2 percent, the nitrogen runoff control treatment level is determined as follows:

- **High treatment**: Sum of structural practice score, residue and tillage management score, and nitrogen management score is equal to 12. (High treatment level for all three treatment types.)
- **Moderately high treatment**: Sum of scores equal to 9, 10, or 11.
- **Moderate treatment**: Sum of scores equal to 6, 7 or 8.
- **Low treatment**: Sum of scores equal to 3, 4, or 5.

Note: About 44 percent of cropped acres in the Chesapeake Bay region is highly erodible land.

**Figure 64**. Conservation treatment levels for phosphorus runoff control in the baseline conservation condition, Chesapeake Bay region




| | Low | Moderate | Moderately high | High |
|---|---|---|---|---|
| HEL | 16.5 | 20.6 | 6.6 | 0.2 |
| Non-HEL | 15.3 | 22.9 | 15.0 | 3.0 |

Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and phosphorus management treatment levels (see figures 10, 11, and 13) in the same manner as the nitrogen runoff control treatment level. Scores were first assigned to these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1.

If slope was 2 percent or less, the phosphorus runoff control treatment level is determined as follows:

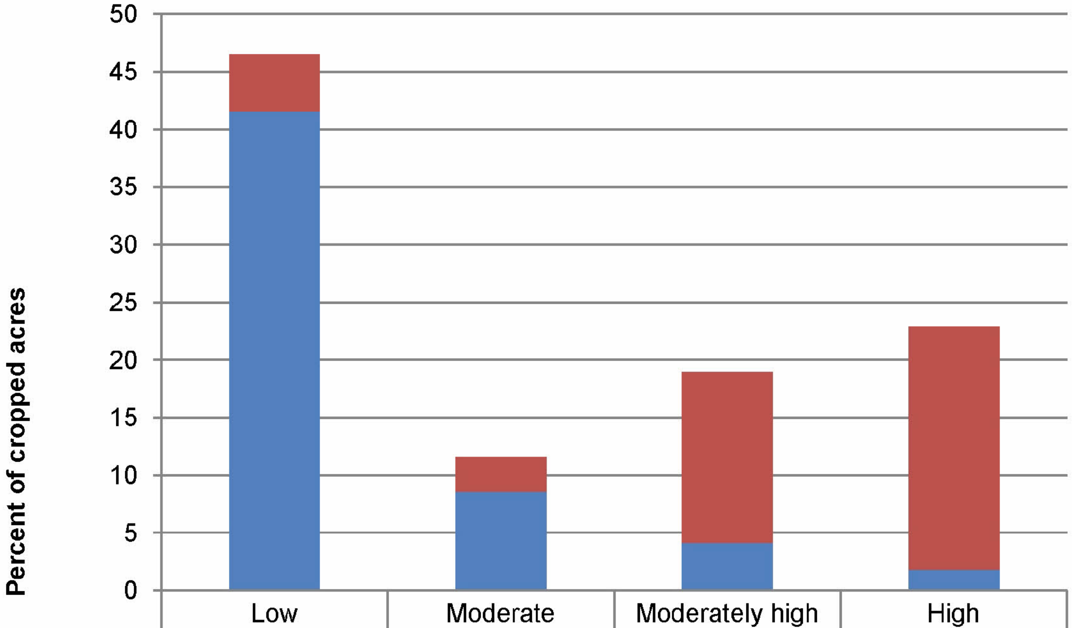
- **High treatment**: Sum of residue and tillage management score and phosphorus management score is equal to 8. (High treatment level for both structural practices and phosphorus management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

If slope was greater than 2 percent, the phosphorus runoff control treatment level is determined as follows:

- **High treatment**: Sum of structural practice score, residue and tillage management score, and phosphorus management score is equal to 12. (High treatment level for all three treatment types.)
- **Moderately high treatment**: Sum of scores equal to 9, 10, or 11.
- **Moderate treatment**: Sum of scores equal to 6, 7 or 8.
- **Low treatment**: Sum of scores equal to 3, 4, or 5.

Note: About 44 percent of cropped acres in the Chesapeake Bay region is highly erodible land.

**Figure 65**. Soil runoff potential for cropped acres in the Chesapeake Bay region




| | Low | Moderate | Moderately high | High |
|---|---|---|---|---|
| HEL | 5.0 | 3.0 | 14.8 | 21.1 |
| Non-HEL | 41.6 | 8.6 | 4.2 | 1.8 |

Criteria for four classes of soil runoff potential were derived using a combination of soil hydrologic group, slope, and K-factor, as shown in the table below:

| Soil runoff potential | Acres with soil hydrologic group A | Acres with soil hydrologic group B | Acres with soil hydrologic group C | Acres with soil hydrologic group D |
|---|---|---|---|---|
| Low | All acres | Slope<4 | Slope<2 | Slope<2 and K-factor<0.28 |
| Moderate | None | Slope >=4 and <=6 and K-factor<0.32 | Slope >=2 and <=6 and K-factor<0.28 | Slope<2 and K-factor>=0.28 |
| Moderately high | None | Slope >=4 and <=6 and K-factor>=0.32 | Slope >=2 and <=6 and K-factor>=0.28 | Slope >=2 and <=4 |
| High | None | Slope>6 | Slope>6 | Slope>4 |

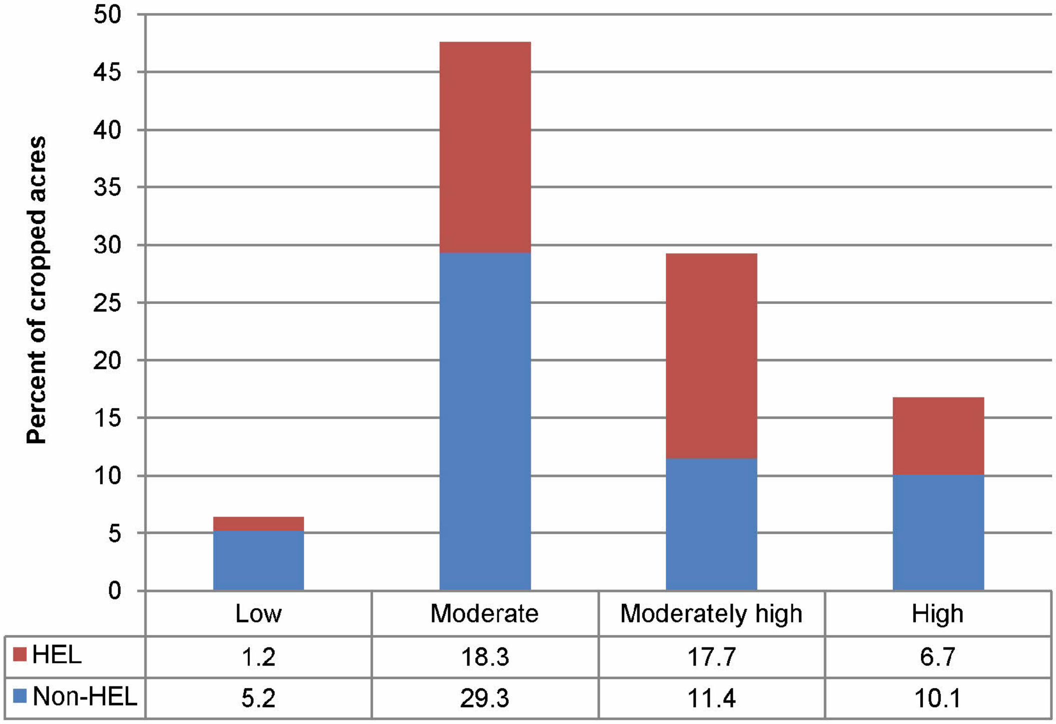
Hydrologic soil groups are classified as:

- **Group A—**sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- **Group B**—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- **Group C**—sandy clay loam soils that have low infiltration rates when thoroughly wetted.
- **Group D**—clay loam, silty clay loam, sandy clay, silty clay, or clay soils that have very low infiltration rates when thoroughly wetted.

K-factor is a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. It is determined by the composition of the soil, saturated hydraulic conductivity, and soil structure.

Note: About 44 percent of cropped acres in the Chesapeake Bay region is highly erodible land.

**Figure 66**. Soil leaching potential for cropped acres in the Chesapeake Bay region




Criteria for four classes of soil leaching potential were derived using a combination of soil hydrologic group, slope, and K-factor, as shown in the table below:

| Soil leaching potential | Acres with soil hydrologic group A | Acres with soil hydrologic group B | Acres with soil hydrologic group C | Acres with soil hydrologic group D |
|---|---|---|---|---|
| Low | None | None | None | All acres except organic soils |
| Moderate | None | Slope <=12 and K-factor>=0.24 or slope>12 | All acres except organic soils | None |
| Moderately high | Slope>12 | Slope >=3 and <=12 and K-factor<0.24 | None | None |
| High | Slope<=12 or acres classified as organic soils | Slope<3 and K-factor <0.24 or acres classified as organic soils | Acres classified as organic soils | Acres classified as organic soils |

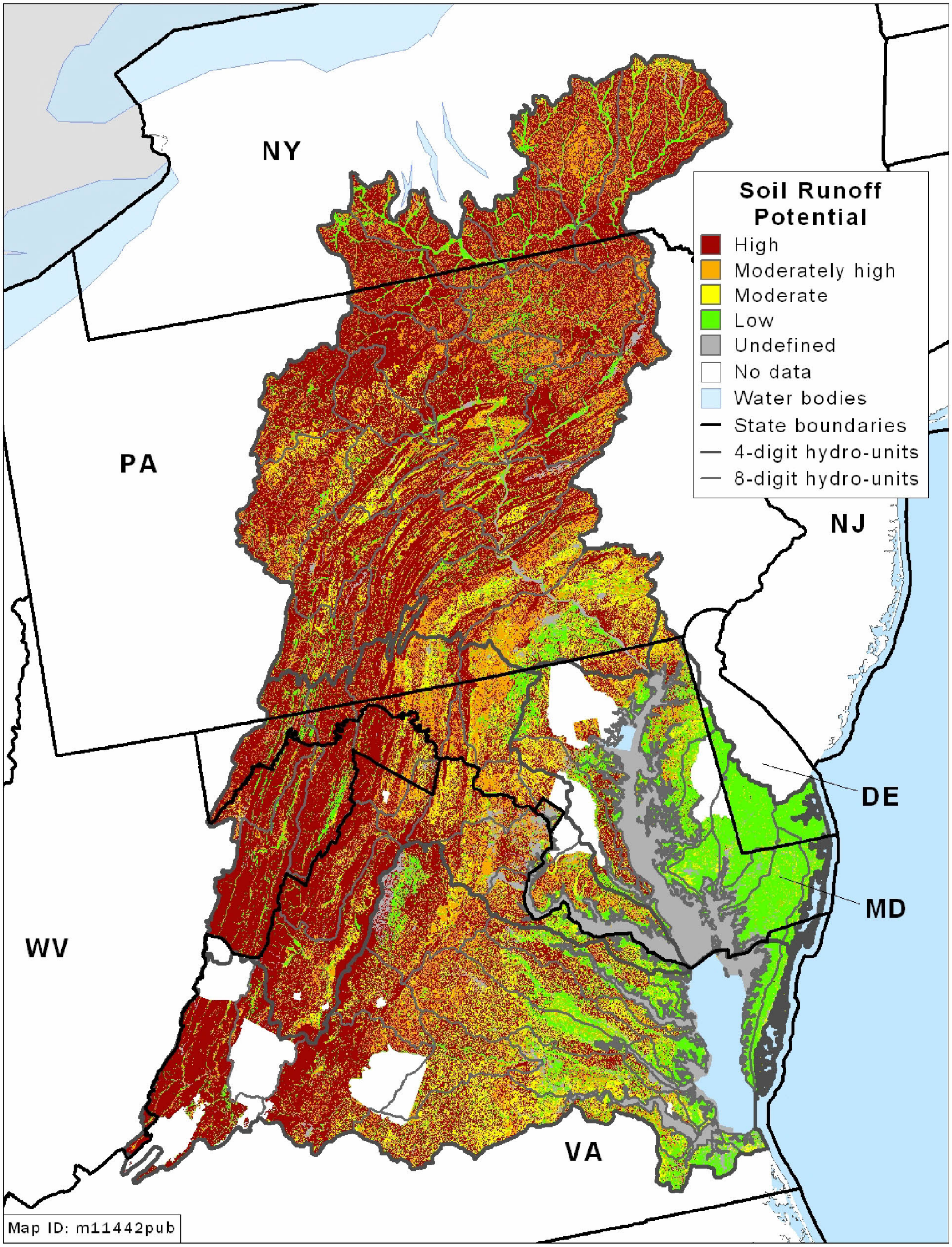
Coarse fragments (stones and rocks) in the soil make it easier for water to infiltrate rather than run off. If the coarse fragment content of the soil was greater than 30 percent, the soil leaching potential was increased two levels (moderate and moderately high to high, and low to moderately high). If the coarse fragment content was greater than 10 percent but less than 30 percent, the soil leaching potential was increased one level.

Hydrologic soil groups are classified as:

- **Group A—**sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- **Group B**—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- **Group C**—sandy clay loam soils that have low infiltration rates when thoroughly wetted.
- **Group D**—clay loam, silty clay loam, sandy clay, silty clay, or clay soils that have very low infiltration rates when thoroughly wetted.

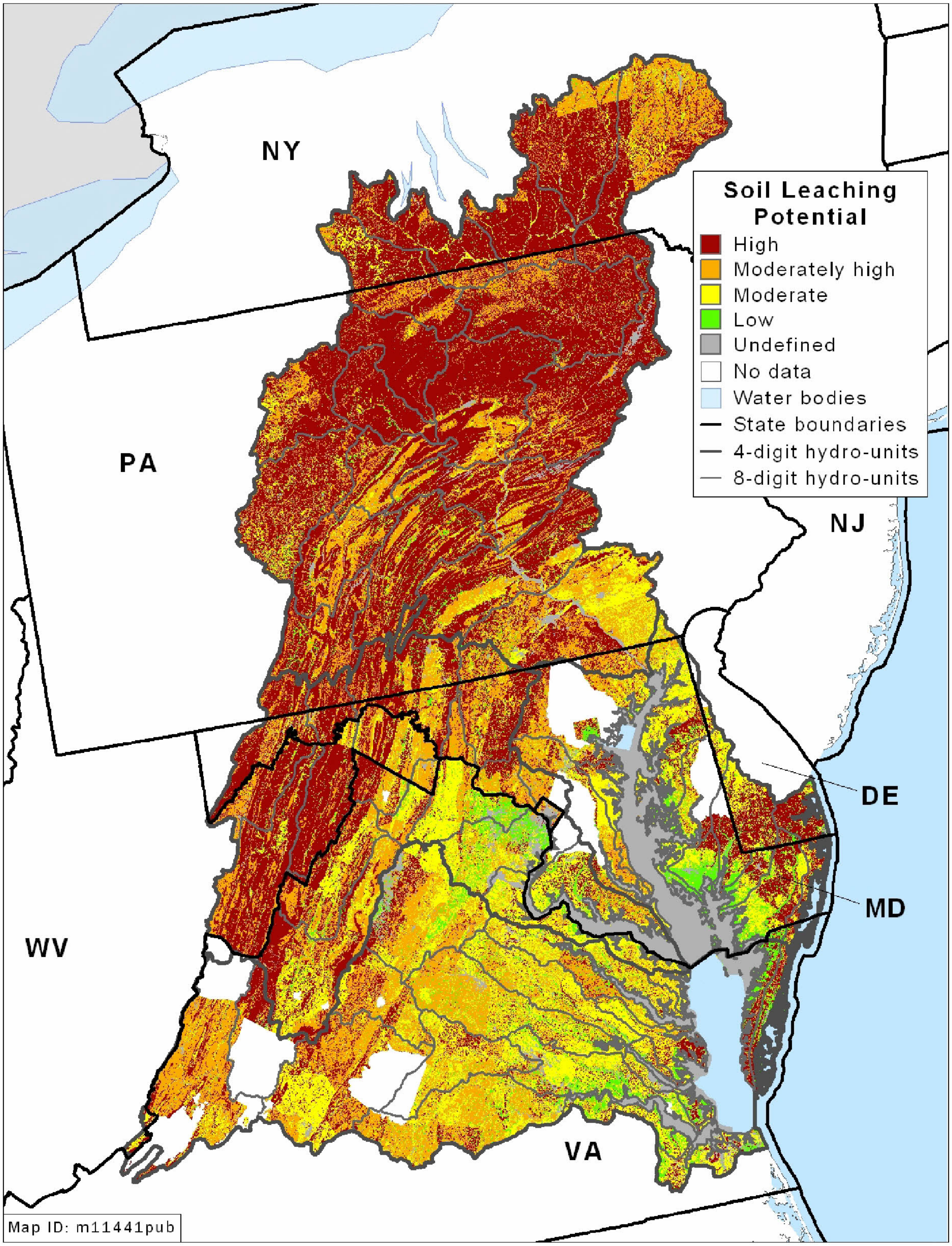
K-factor is a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. It is determined by the composition of the soil, saturated hydraulic conductivity, and soil structure.
Note: About 44 percent of cropped acres in the Chesapeake Bay region is highly erodible land.

**Figure 67**. Soil runoff potential for soils in the Chesapeake Bay region




Note: The soil runoff potential shown in this map was derived using the criteria presented in figure 65 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

**Figure 68**. Soil leaching potential for soils in the Chesapeake Bay region




Note: The soil leaching potential shown in this map was derived using the criteria presented in figure 66 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

## Evaluation of Conservation Treatment

Levels of conservation treatment in the baseline conservation condition were evaluated using both the level of conservation treatment and vulnerability factors, as shown in tables 37 through 40. Breaking down the acres into 16 groups (four soil potentials and four treatment levels) reveals the following trends:

- Estimates of sediment and nutrient loss for the no-practice scenario consistently increased from small losses for the low soil runoff or leaching potential to large losses for the high soil runoff or leaching potential. As this scenario represents crop production without conservation practices, there is no consistent relationship in loss estimates among the four conservation treatment levels. The differences in losses among conservation treatment levels reflect the underlying variability, which is also influenced by the number of acres in each group.
- Estimates of sediment and nutrient loss for the baseline conservation condition, which includes conservation practices in use in the Chesapeake Bay region, exhibit a nearly consistent trend of decreasing loss with increasing treatment level within each soil runoff or leaching potential. The high treatment level is effective in reducing losses to acceptable levels for all soil potentials, as shown in figures 69-72.
- The highest losses in the baseline conservation condition were for groups of acres where the conservation treatment level was one step or more below the soil leaching or runoff potential.

The evaluation of conservation treatment needs was conducted by identifying which of the 16 groups of acres were inadequately treated with respect to the soil runoff or soil leaching potential. To complete the evaluation, it was necessary to define thresholds for acceptable levels of sediment and nutrient loss from the field. Scientific literature on field research and edge-of-field monitoring provided guidance for identifying these thresholds. Model simulation of additional conservation practices (described in chapter 7) was also used to derive acceptable levels to ensure that the levels were possible to attain with traditional conservation and were agronomically feasible within the Chesapeake Bay region.

Acceptable levels for field-level losses used in this study to evaluate the adequacy of conservation treatment follow:

- Average of 2 tons per acre per year for sediment loss
- Average of 15 pounds per acre per year for nitrogen lost to surface water (soluble and sediment attached)
- Average of 25 pounds per acre per year for nitrogen loss in subsurface flows
- Average of 4 pounds per acre per year for phosphorus lost to surface water (soluble and sediment attached)

These acceptable levels represent field losses that are feasible to attain using traditional conservation treatment consisting of nutrient management and soil erosion control. The percentage of acres in the Chesapeake Bay region that can attain these acceptable levels with additional soil erosion control and nutrient management practices, as defined in chapter 7, are:

- 99 percent of acres for sediment loss
- 99 percent of acres for nitrogen lost to surface water
- 86 percent of acres for nitrogen loss in subsurface flows
- 95 percent of acres for phosphorus lost to surface water

Acceptable levels were not used directly to identify specific acres that need additional treatment. Rather, acceptable levels were used to identify groups of acres where the conservation treatment level was most likely inadequate *relative to the inherent vulnerability* of the acres in that group to export soil or nutrients from the field. Thus, the vulnerability and conservation treatment condition associated with acres that need additional treatment is explicitly identified, providing a convenient framework for implementation of targeting strategies.

These acceptable levels are used in this study only as an indication of inadequate conservation treatment at the field level. They are not intended to provide adequate protection of water quality, although for some environments they may be suitable for this purpose.

## Under-Treated Acres

Two groups of acres needing treatment were identified: 1) under-treated acres, and 2) critical under-treated acres, a subset of under-treated acres.

The percent of acres in each of the 16 groups that exceeded the acceptable levels was calculated, presented in tables 37 through 40, to serve as an indication of adequate treatment for each group of acres. Groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. These are acres where field-level losses are most likely not being controlled adequately with the existing level of treatment and where additional conservation treatment is needed. Critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels. In a few cases, these criteria were adjusted slightly to preserve the vulnerability trends shown in the tables. Critical under-treated acres represent the most vulnerable acres in the region, usually consisting of acres with a high or moderately high soil runoff or leaching potential.

High levels of treatment were shown by model simulations to provide good protection on the most vulnerable acres. Less vulnerable acres were often adequately treated with a low, moderate, or moderately high level of conservation treatment.

Many of the more vulnerable acres with less conservation treatment, however, require additional conservation practices:

- 1.1 million acres (26 percent of cropped acres) require additional treatment for sediment loss due to water erosion (table 37). All 1.1 million are critically under-treated.

- 1.2 million acres (27 percent of cropped acres) require additional treatment for nitrogen lost to surface water (table 38). Seventy-five percent of the 1.2 million under-treated acres are critically under-treated.
- 2.8 million acres (65 percent of cropped acres) require additional treatment for nitrogen loss in subsurface flows (table 39). Twenty-eight percent of the 2.8 million acres are critically under-treated.
- 2.2 million acres (51 percent of cropped acres) require additional treatment for phosphorus lost to surface water (table 40). Forty-two percent of the 2.2 million under-treated acres critically under-treated.

Some acres required treatment for only one of the four resource concerns, while other acres require additional treatment for two or more. After accounting for acres that need treatment for multiple resource concerns, the evaluation of treatment needs for the Chesapeake Bay region determined the following (table 41):

- 0.8 million acres (19 percent of cropped acres) are adequately treated for all four resource concerns.
- 3.5 million acres (81 percent of cropped acres) are under-treated for one or more of the four resource concerns that were evaluated:
  - 28 percent of cropped acres require additional treatment only for nitrogen loss in subsurface flows,
  - 16 percent of cropped acres require additional treatment for sediment loss, nitrogen leaching, runoff, *and* phosphorus runoff, and
  - 16 percent of cropped acres require additional treatment only for all nitrogen leaching and phosphorus runoff.
- 2.0 million of these acres (47 percent of cropped acres) are critical under-treated acres, consisting of the most vulnerable and/or under-treated acres with the highest losses in the region.
- About 35 percent of the under-treated acres need additional treatment for only one of the four resource concerns, usually nitrogen leaching.
- For critical under-treated acres, only 21 percent need additional treatment for only one resource concern; thus 4 out of 5 of these acres need treatment for *multiple* resource concerns.

Losses for under-treated acres are much higher, on average, than losses for adequately treated acres, as shown in table 42. For example, sediment loss in the baseline conservation condition averages 2.4 tons per acre per year for critical under-treated acres, compared to 0.6 ton per acre per year for non-critical under-treated acres and only 0.4 ton per acre for the remaining acres. Total nitrogen loss averages 68 pounds per acre for the critical under-treated acres and 49 pounds per acre for the non-critical under-treated acres, compared to only 21 pounds per acre for the remaining acres. Total phosphorus loss averages 5.8 pounds per acre for the critical under-treated acres and 2.8 pounds per acre for the non-critical under-treated acres, compared to only 1.0 pounds per acre for the remaining acres.

The distribution of under-treated acres among the 4 subbasins within the Chesapeake Bay region is presented in table 43. Percentages of the under-treated acres in the Chesapeake Bay region that are in each subbasin are close to the same percentages of the region's cultivated cropland in each subbasin, indicating that under-treated acres are spread proportionately throughout the region. Critical under-treated acres, however, are disproportionately high in the Susquehanna River subbasin relative to the percentage of cropped acres. In this region, 66 percent of the cropped acres are critically under-treated. Critical under-treated acres are disproportionately low in the Upper Chesapeake subbasin relative to the percentage of cropped acres.

The breakdown of under-treated acres by cropping system showed a proportionate distribution of under-treated acres among cropping systems, shown in table 44. For the critical under-treated acres, however, a disproportionately higher percentage occurs for three cropping systems—hay-crop mixes, corn only, and corn grown in rotation with close-grown crops—indicating that these cropping systems tend to occur more frequently on the more vulnerable acres within the region.

**Figure 69.** Trend in average annual sediment loss for increasing levels of soil runoff potential at two levels of conservation treatment.

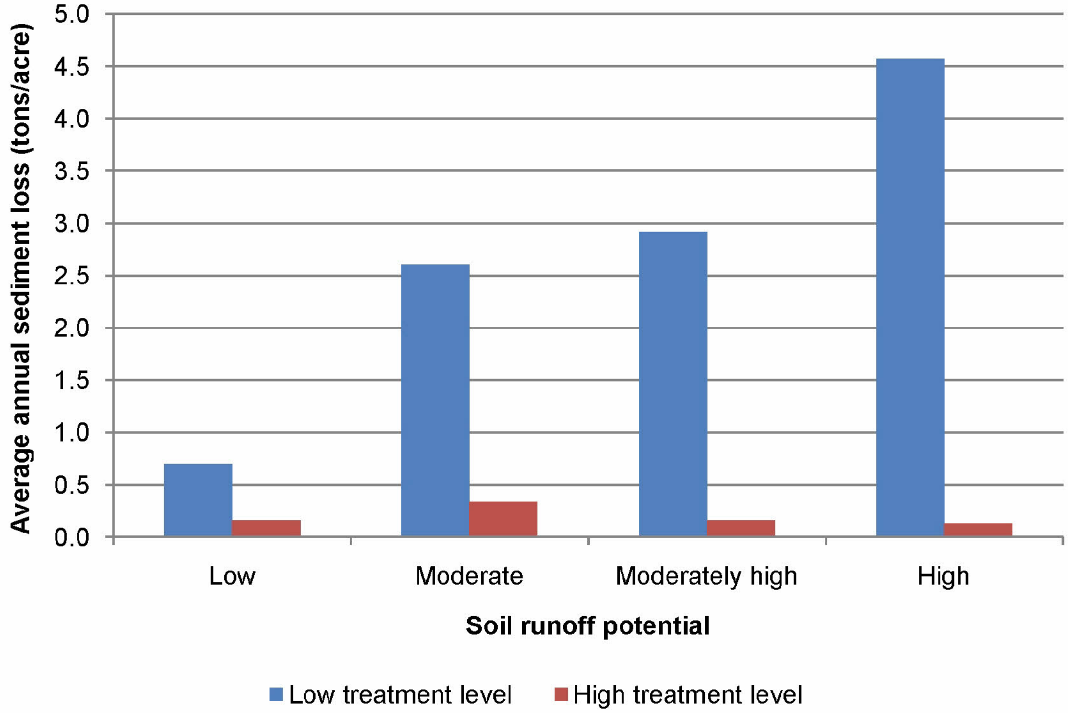
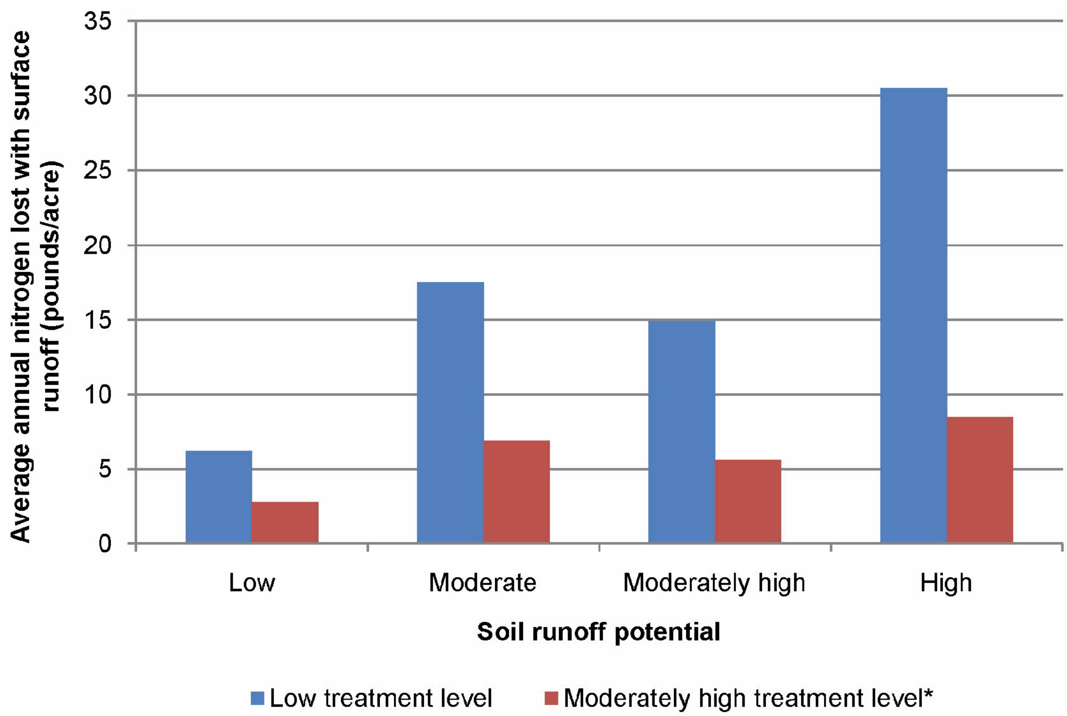



**Figure 70.** Trend in average annual nitrogen lost to surface water for increasing levels of soil runoff potential at two levels of conservation treatment.




* There was not sufficient sample size to report values for the high treatment class.

**Figure 71.** Trend in average annual nitrogen loss in subsurface flows for increasing levels of soil leaching potential at two levels of conservation treatment

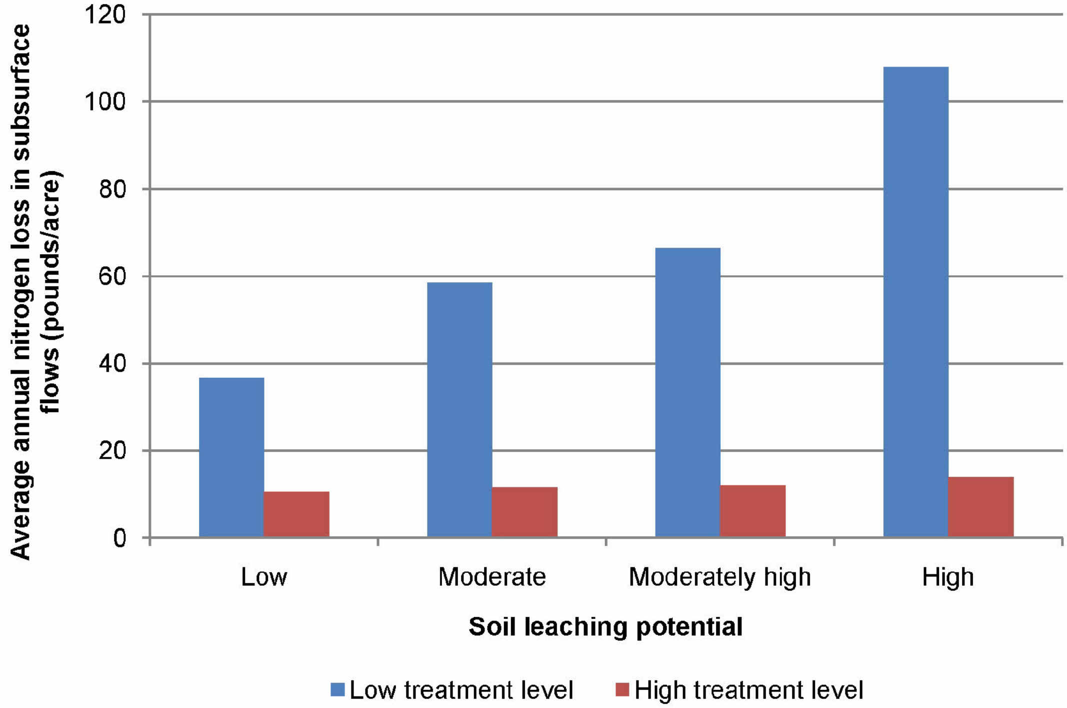
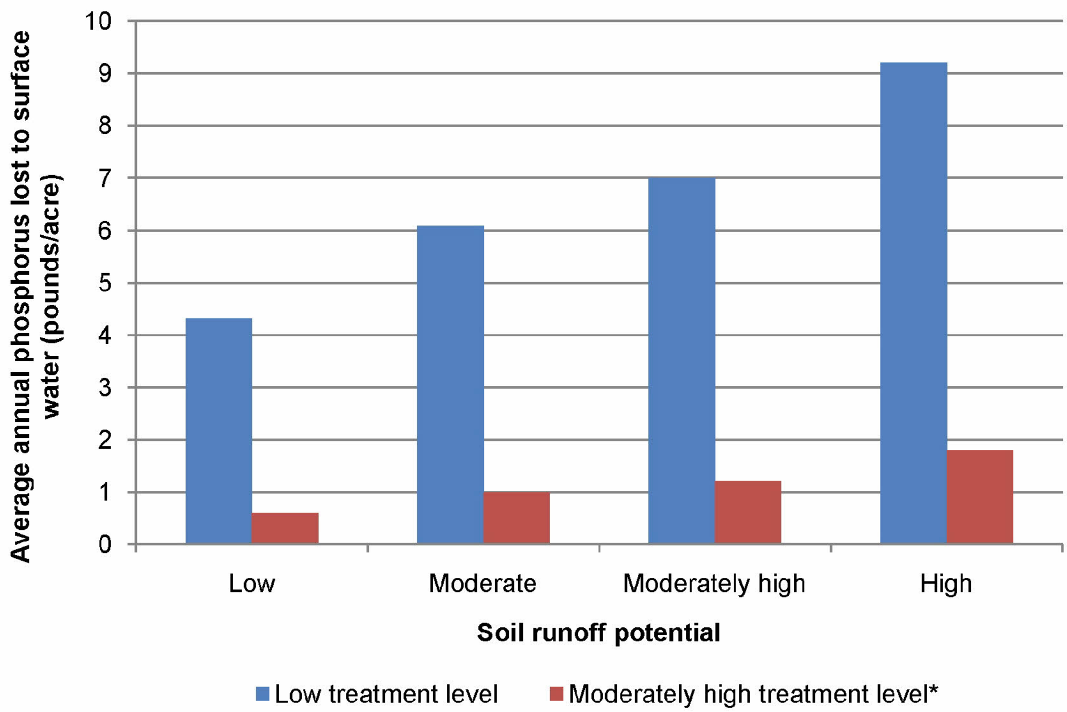



**Figure 72.** Trend in average annual phosphorus lost to surface water for increasing levels of soil runoff potential at two levels of conservation treatment




* There was not sufficient sample size to report values for the high treatment class.

**Table 37**. Identification of under-treated acres for sediment loss due to water erosion in the Chesapeake Bay region

| | Conservation treatment levels for water erosion control | | | | |
|---|---|---|---|---|---|
| Soil runoff potential | Low | Moderate | Moderately high | High | All |
| Estimated cropped acres | | | | | |
| Low | 241,016 | 962,950 | 221,902 | 566,546 | 1,992,414 |
| Moderate | 130,299 | 282,265 | 48,963 | 34,493 | 496,021 |
| Moderately high | 216,699 | 420,230 | 131,076 | 44,135 | 812,140 |
| High | 225,334 | 541,230 | 181,725 | 31,036 | 979,325 |
| All | 813,348 | 2,206,676 | 583,667 | 676,210 | 4,279,900 |
| Percent of cropped acres | | | | | |
| Low | 6 | 23 | 5 | 13 | 47 |
| Moderate | 3 | 7 | 1 | 1 | 12 |
| Moderately high | 5 | 10 | 3 | 1 | 19 |
| High | 5 | 13 | 4 | 1 | 23 |
| All | 19 | 52 | 14 | 16 | 100 |
| Sediment loss estimates *without* conservation practices (no-practice scenario, average annual tons/acre/year) | | | | | |
| Low | 1.14 | 1.06 | 1.79 | 0.86 | 1.10 |
| Moderate | 3.41 | 2.45 | 5.76 | 0.93 | 2.93 |
| Moderately high | 4.64 | 3.86 | 4.86 | 3.49 | 4.21 |
| High | 7.65 | 10.65 | 8.67 | 8.68 | 9.53 |
| All | 4.24 | 4.12 | 4.95 | 1.40 | 3.83 |
| Sediment loss estimates for the baseline conservation condition (average annual tons/acre/year) | | | | | |
| Low | 0.70 | 0.48 | 0.24 | 0.16 | 0.39 |
| Moderate | 2.60 | 0.77 | 0.76 | 0.34 | 1.22 |
| Moderately high | 2.92 | 1.38 | 0.90 | 0.16 | 1.65 |
| High | 4.57 | 4.05 | 1.14 | 0.13 | 3.51 |
| All | 2.67 | 1.56 | 0.71 | 0.17 | 1.44 |
| Percent reduction in sediment loss due to conservation practices | | | | | |
| Low | 38 | 55 | 87 | 81 | 64 |
| Moderate | 24 | 68 | 87 | 63 | 58 |
| Moderately high | 37 | 64 | 81 | 95 | 61 |
| High | 40 | 62 | 87 | 98 | 63 |
| All | 37 | 62 | 86 | 88 | 62 |
| Percent of acres in baseline conservation condition with average annual sediment loss more than 2 tons/acre | | | | | |
| Low | 4 | 5 | 0 | 0 | 3 |
| Moderate | 72 | 6 | 0 | 0 | 22 |
| Moderately high | 52* | 20 | 13 | 0 | 26 |
| High | 82 | 64 | 21 | 0 | 58 |
| All | 49 | 22 | 10 | 0 | 22 |
| Estimate of under-treated acres | | | | | |
| Low | 0 | 0 | 0 | 0 | 0 |
| Moderate | 130,299 | 0 | 0 | 0 | 130,299 |
| Moderately high | 216,699 | 0 | 0 | 0 | 216,699 |
| High | 225,334 | 541,230 | 0 | 0 | 766,564 |
| All | 572,332 | 541,230 | 0 | 0 | 1,113,563 |

Note: Cells below the red boundary shown for the baseline conservation condition are the acres where the level of conservation treatment is one step or more below the soil runoff potential. These cells consistently had the highest losses in the model simulations.
Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Percents may not add to totals because of rounding.
* This group of acres was classified as critical under-treated acres because the next lowest soil runoff potential met the criteria for critical under-treated acres.

**Table 38**. Identification of under-treated acres for nitrogen loss with surface runoff (sediment attached and soluble) in the Chesapeake Bay region

| Soil runoff potential | Conservation treatment levels for nitrogen runoff control: Low | Moderate | Moderately high | High | All |
|---|---|---|---|---|---|
| **Estimated cropped acres** | | | | | |
| Low | 330,583 | 1,040,680 | 603,245 | * | 1,992,414 |
| Moderate | 124,208 | 301,076 | 70,737 | * | 496,021 |
| Moderately high | 171,712 | 494,784 | 145,644 | * | 812,140 |
| High | 184,546 | 688,261 | 106,518 | * | 979,325 |
| All | 811,050 | 2,524,802 | 926,143 | 17,906 | 4,279,900 |
| **Percent of cropped acres** | | | | | |
| Low | 8 | 24 | 14 | * | 47 |
| Moderate | 3 | 7 | 2 | * | 12 |
| Moderately high | 4 | 12 | 3 | * | 19 |
| High | 4 | 16 | 2 | * | 23 |
| All | 19 | 59 | 22 | <1 | 100 |
| **Estimates of nitrogen loss with surface runoff *without* conservation practices (no-practice scenario, average annual pounds/acre/year)** | | | | | |
| Low | 9.9 | 5.9 | 5.2 | * | 6.3 |
| Moderate | 18.9 | 12.0 | 12.8 | * | 13.9 |
| Moderately high | 22.1 | 19.8 | 13.4 | * | 19.1 |
| High | 47.4 | 35.8 | 30.6 | * | 37.4 |
| All | 22.4 | 17.5 | 10.0 | * | 16.7 |
| **Estimates of nitrogen loss with surface runoff for the baseline conservation condition (average annual pounds/acre/year)** | | | | | |
| Low | 6.2 | 3.3 | 2.8 | * | 3.6 |
| Moderate | 12.5 | 6.4 | 6.9 | * | 8.0 |
| Moderately high | 14.9 | 11.7 | 5.6 | * | 11.3 |
| High | 30.5 | 21.6 | 8.5 | * | 21.9 |
| All | 14.5 | 10.3 | 4.2 | * | 9.7 |
| **Percent reduction in nitrogen loss with surface runoff due to conservation practices** | | | | | |
| Low | 37 | 45 | 47 | * | 43 |
| Moderate | 34 | 47 | 46 | * | 42 |
| Moderately high | 32 | 41 | 58 | * | 41 |
| High | 36 | 40 | 72 | * | 42 |
| All | 35 | 41 | 58 | * | 42 |
| **Percent of acres in baseline conservation condition with average annual nitrogen loss with surface runoff more than 15 pounds/acre** | | | | | |
| Low | 16 | 1 | 0 | * | 3 |
| Moderate | 33 | 4 | 0 | * | 10 |
| Moderately high | 28* | 23 | 5 | * | 21 |
| High | 90 | 60 | 9 | * | 60 |
| All | 38 | 22 | 2 | 0 | 20 |
| **Estimate of under-treated acres for nitrogen loss with surface runoff** | | | | | |
| Low | 0 | 0 | 0 | 0 | 0 |
| Moderate | 124,208 | 0 | 0 | 0 | 124,208 |
| Moderately high | 171,712 | 0 | 0 | 0 | 171,712 |
| High | 184,546 | 688,261 | 0 | 0 | 872,807 |
| All | 480,466 | 688,261 | 0 | 0 | 1,168,728 |

Note: Cells below the red boundary shown for the baseline conservation condition are the acres where the level of conservation treatment is one step or more below the soil runoff potential. These cells consistently had the highest losses in the model simulations.
Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Percents may not add to totals because of rounding.
* Estimate not reported because there were only 3 or fewer sample points available in the category.
* This group of acres was classified as under-treated acres because the next lowest soil runoff potential met the criteria for under-treated acres.

**Table 39**. Identification of under-treated acres for nitrogen loss in subsurface flows in the Chesapeake Bay region

| Soil leaching potential | Conservation treatment levels for nitrogen management: Low | Moderate | Moderately high | High | All |
|---|---|---|---|---|---|
| **Estimated cropped acres** | | | | | |
| Low | 63,413 | 103,703 | 71,640 | 36,284 | 275,040 |
| Moderate | 481,440 | 873,736 | 505,311 | 177,772 | 2,038,260 |
| Moderately high | 277,231 | 490,980 | 390,333 | 90,622 | 1,249,166 |
| High | 151,197 | 340,017 | 144,120 | 82,100 | 717,434 |
| All | 973,282 | 1,808,437 | 1,111,403 | 386,778 | 4,279,900 |
| **Percent of cropped acres** | | | | | |
| Low | 1 | 2 | 2 | 1 | 6 |
| Moderate | 11 | 20 | 12 | 4 | 48 |
| Moderately high | 6 | 11 | 9 | 2 | 29 |
| High | 4 | 8 | 3 | 2 | 17 |
| All | 23 | 42 | 26 | 9 | 100 |
| **Estimates of nitrogen loss in subsurface flows *without* conservation practices (no-practice scenario, average annual pounds/acre/year)** | | | | | |
| Low | 53.1 | 34.9 | 17.3 | 23.2 | 33.0 |
| Moderate | 73.2 | 41.9 | 28.9 | 29.7 | 45.0 |
| Moderately high | 91.9 | 46.8 | 43.3 | 28.5 | 54.4 |
| High | 130.4 | 56.8 | 41.4 | 25.8 | 65.7 |
| All | 86.1 | 45.6 | 34.8 | 28.0 | 50.4 |
| **Estimates of nitrogen loss in subsurface flows for the baseline conservation condition (average annual pounds/acre/year)** | | | | | |
| Low | 36.7 | 30.2 | 8.5 | 10.5 | 23.5 |
| Moderate | 58.5 | 31.6 | 10.4 | 11.5 | 30.9 |
| Moderately high | 66.5 | 35.5 | 13.5 | 11.9 | 33.8 |
| High | 108.0 | 42.9 | 18.2 | 14.0 | 48.3 |
| All | 67.0 | 34.7 | 12.3 | 12.0 | 34.2 |
| **Percent reduction in nitrogen loss in subsurface flows due to conservation practices** | | | | | |
| Low | 31 | 14 | 51 | 55 | 29 |
| Moderate | 20 | 25 | 64 | 61 | 31 |
| Moderately high | 28 | 24 | 69 | 58 | 38 |
| High | 17 | 25 | 56 | 46 | 26 |
| All | 22 | 24 | 65 | 57 | 32 |
| **Percent of acres in baseline conservation condition with average annual nitrogen loss in subsurface flows more than 25 pounds/acre** | | | | | |
| Low | 41 | 44 | 9 | 0 | 28 |
| Moderate | 55 | 43 | 5 | 7 | 33 |
| Moderately high | 67 | 52 | 8 | 6 | 38 |
| High | 87 | 60 | 25 | 0 | 52 |
| All | 62 | 49 | 9 | 5 | 37 |
| **Estimate of under-treated acres for nitrogen loss in subsurface flows** | | | | | |
| Low | 63,413 | 103,703 | 0 | 0 | 167,116 |
| Moderate | 481,440 | 873,736 | 0 | 0 | 1,355,177 |
| Moderately high | 277,231 | 490,980 | 0 | 0 | 768,212 |
| High | 151,197 | 340,017 | 0 | 0 | 491,215 |
| All | 973,282 | 1,808,437 | 0 | 0 | 2,781,719 |

Note: Cells below the red boundary shown for the baseline conservation condition are the acres where the level of conservation treatment is one step or more below the soil leaching potential. These cells consistently had the highest losses in the model simulations.
Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Percents may not add to totals because of rounding.

**Table 40**. Identification of under-treated acres for phosphorus lost to surface water (sediment attached and soluble) in the Chesapeake Bay region

| Soil runoff potential | Conservation treatment levels for phosphorus runoff control: Low | Moderate | Moderately high | High | All |
|---|---|---|---|---|---|
| **Estimated cropped acres** | | | | | |
| Low | 440,880 | 829,361 | 598,142 | 124,031 | 1,992,414 |
| Moderate | 205,363 | 203,434 | 87,224 | * | 496,021 |
| Moderately high | 284,357 | 391,220 | 126,525 | * | 812,140 |
| High | 430,078 | 435,930 | 113,317 | * | 979,325 |
| All | 1,360,678 | 1,859,945 | 925,208 | 134,069 | 4,279,900 |
| **Percent of cropped acres** | | | | | |
| Low | 10 | 19 | 14 | 3 | 47 |
| Moderate | 5 | 5 | 2 | * | 12 |
| Moderately high | 7 | 9 | 3 | * | 19 |
| High | 10 | 10 | 3 | * | 23 |
| All | 32 | 43 | 22 | 3 | 100 |
| **Phosphorus lost to surface water *without* conservation practices (no-practice scenario, average annual pounds/acre/year)** | | | | | |
| Low | 5.99 | 2.86 | 3.01 | 3.08 | 3.61 |
| Moderate | 8.58 | 6.21 | 4.98 | * | 6.97 |
| Moderately high | 9.79 | 8.14 | 6.25 | * | 8.41 |
| High | 14.23 | 9.52 | 6.78 | * | 11.27 |
| All | 9.78 | 5.90 | 4.10 | 3.38 | 6.66 |
| **Phosphorus lost to surface water for the baseline conservation condition (average annual pounds/acre/year)** | | | | | |
| Low | 4.31 | 1.68 | 0.60 | 0.40 | 1.86 |
| Moderate | 6.08 | 2.88 | 1.00 | * | 3.88 |
| Moderately high | 7.00 | 4.79 | 1.21 | * | 4.95 |
| High | 9.21 | 5.11 | 1.80 | * | 6.52 |
| All | 6.69 | 3.27 | 0.87 | 0.41 | 3.75 |
| **Percent reduction in phosphorus lost to surface water due to conservation practices** | | | | | |
| Low | 28 | 41 | 80 | 87 | 49 |
| Moderate | 29 | 54 | 80 | * | 44 |
| Moderately high | 28 | 41 | 81 | * | 41 |
| High | 35 | 46 | 73 | * | 42 |
| All | 32 | 45 | 79 | 88 | 44 |
| **Percent of acres in baseline conservation condition with average annual phosphorus lost to surface water more than 4 pounds/acre** | | | | | |
| Low | 36 | 10 | 1 | 0 | 12 |
| Moderate | 67 | 24 | 0 | * | 38 |
| Moderately high | 54** | 36 | 6 | * | 37 |
| High | 75 | 40 | 14 | * | 52 |
| All | 57 | 24 | 3 | 0 | 29 |
| **Estimate of under-treated acres for phosphorus lost to surface water** | | | | | |
| Low | 440,880 | 0 | 0 | 0 | 440,880 |
| Moderate | 205,363 | 0 | 0 | 0 | 205,363 |
| Moderately high | 284,357 | 391,220 | 0 | 0 | 675,576 |
| High | 430,078 | 435,930 | 0 | 0 | 866,008 |
| All | 1,360,678 | 827,150 | 0 | 0 | 2,187,828 |

Note: Cells below the red boundary shown for the baseline conservation condition are the acres where the level of conservation treatment is one step or more below the soil runoff potential. These cells consistently had the highest losses in the model simulations.
Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Percents may not add to totals because of rounding.
* Estimate not reported because there were only 3 or fewer sample points available in the category.
** This group of acres was classified as critical under-treated acres because the next lowest soil runoff potential met the criteria for critical under-treated acres.

**Table 41.** Under-treated acres with resource concerns needing treatment in the Chesapeake Bay region

| Reasons for treatment need | | Estimated acres needing treatment | Percent of cropped acres |
|---|---|---|---|
| **All under-treated acres** | | | |
| Nitrogen leaching only | | 1,221,403 | 28.5 |
| Sediment, nitrogen and phosphorus runoff, and nitrogen leaching | | 696,612 | 16.3 |
| Nitrogen leaching and phosphorus runoff | | 686,415 | 16.0 |
| Sediment, nitrogen runoff and phosphorus runoff | | 294,827 | 6.9 |
| Phosphorus runoff only | | 271,871 | 6.4 |
| Nitrogen runoff, phosphorus runoff, and nitrogen leaching | | 135,882 | 3.2 |
| Sediment and phosphorus runoff | | 102,220 | 2.4 |
| Nitrogen leaching and nitrogen runoff | | 35,940 | 0.8 |
| Sediment only | | 14,438 | 0.3 |
| Sediment, nitrogen runoff, and nitrogen leaching | | 5,466 | 0.1 |
| | Total | 3,465,075 | 81.0 |
| **Critical under-treated acres** | | | |
| Nitrogen leaching only | | 551,250 | 12.9 |
| Sediment, nitrogen runoff and phosphorus runoff | | 394,790 | 9.2 |
| Sediment and nitrogen runoff | | 267,104 | 6.2 |
| Phosphorus runoff only | | 215,120 | 5.0 |
| Sediment and phosphorus runoff | | 206,416 | 4.8 |
| Sediment only | | 83,462 | 2.0 |
| Sediment, nitrogen runoff, and nitrogen leaching | | 69,383 | 1.6 |
| Nitrogen runoff only | | 68,496 | 1.6 |
| Sediment, phosphorus runoff, and nitrogen leaching | | 50,526 | 1.2 |
| Nitrogen leaching and nitrogen runoff | | 37,747 | 0.9 |
| Sediment, nitrogen and phosphorus runoff, and nitrogen leaching | | 35,288 | 0.8 |
| Nitrogen leaching and phosphorus runoff | | 17,658 | 0.4 |
| Sediment and nitrogen leaching | | 6,595 | 0.2 |
| | Total | 2,003,834 | 46.8 |

Note: This table summarizes the under-treated acres identified in tables 37-40 and reports the joint set of acres that need treatment according to combinations of resource concerns.
Note: Percents may not add to totals because of rounding.

**Table 42**. Baseline conservation condition model simulation results for subsets of under-treated and adequately treated acres in the Chesapeake Bay region

| Model simulated outcome | Critical under-treated acres | Non-critical under-treated acres | Adequately treated acres | All acres |
|---|---|---|---|---|
| **Cultivated cropland acres in subset** | 2,003,834 | 1,461,240 | 814,825 | 4,279,900 |
| Percent of acres | 46.8% | 34.1% | 19.0% | 100% |
| **Water flow** | | | | |
| Average annual surface runoff (inches) | 4.2 | 4.7 | 4.7 | 4.5 |
| Average annual subsurface water flow (inches) | 11.2 | 11.3 | 12.6 | 11.5 |
| **Erosion and sediment loss** | | | | |
| Average annual wind erosion (tons/acre) | 0.020 | 0.037 | 0.025 | 0.027 |
| Average annual sheet and rill erosion (tons/acre) | 2.3 | 0.9 | 0.6 | 1.5 |
| Average annual sediment loss at edge of field due to water erosion (tons/acre) | 2.4 | 0.6 | 0.4 | 1.4 |
| **Soil organic carbon** | | | | |
| Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre) | -87 | 22 | -19 | -37 |
| **Nitrogen loss** | | | | |
| Nitrogen applied (pounds/acre) | 107 | 104 | 54 | 96 |
| Nitrogen in crop yield removed at harvest (pounds/acre) | 77 | 90 | 85 | 83 |
| Total nitrogen loss for all pathways except harvest (pounds/acre) | 68 | 49 | 21 | 53 |
| Average annual loss of nitrogen through volatilization (pounds/acre) | 7 | 8 | 4 | 7 |
| Average annual nitrogen returned to the atmosphere through denitrification processes (pounds/acre) | 2 | 1 | 1 | 2 |
| Average annual loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre) | 15 | 6 | 4 | 10 |
| Average annual nitrogen loss in subsurface flows (pounds/acre) | 44 | 34 | 12 | 34 |
| **Phosphorus loss** | | | | |
| Phosphorus applied (pounds/acre) | 29.7 | 24.4 | 14.9 | 25.1 |
| Total phosphorus loss for all pathways except harvest (pounds/acre) | 5.8 | 2.8 | 1.0 | 3.9 |
| Loss of phosphorus with surface runoff, including waterborne sediment (pounds/acre) | 5.7 | 2.7 | 0.9 | 3.7 |
| **Pesticide loss** | | | | |
| Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare) | 19.2 | 13.1 | 7.3 | 14.9 |
| Average annual surface water pesticide risk indicator for aquatic ecosystem | 1.9 | 1.3 | 0.7 | 1.5 |
| Average annual surface water pesticide risk indicator for humans | 0.4 | 0.3 | 0.2 | 0.3 |

Note: The values reported in this table for the three subsets of acres are influenced by differences in precipitation, slope, and inherent soil vulnerability in addition to the differences in conservation treatment.

**Table 43.** Under-treated acres for the 4 subbasins in the Chesapeake Bay region

| | | | Critical under-treated acres | | | All under-treated acres | | |
|---|---|---|---|---|---|---|---|---|
| **Sub-basin code** | **Subbasin name** | Percent of cropped acres in Chesapeake Bay region | Acres | Percent of critical under-treated acres in Chesapeake Bay region | Percent of cropped acres in subbasin | Acres | Percent of under-treated acres in Chesapeake Bay region | Percent of cropped acres in subbasin |
| 0205 | Susquehanna River | 41 | 1,139,964 | 57 | 66 | 1,479,468 | 43 | 85 |
| 0206 | Upper Chesapeake Bay | 28 | 292,365 | 15 | 25 | 869,549 | 25 | 73 |
| 0207 | Potomac River | 16 | 397,363 | 20 | 58 | 596,082 | 17 | 87 |
| 0208 | Lower Chesapeake Bay | 16 | 174,142 | 9 | 26 | 519,976 | 15 | 77 |
| | **Total** | 100 | 2,003,834 | 100 | 47 | 3,465,075 | 100 | 81 |

Note: Percents may not add to totals because of rounding.

**Table 44.** Under-treated acres by cropping system in the Chesapeake Bay region

| | | Critical under-treated acres | | | All under-treated acres | | |
|---|---|---|---|---|---|---|---|
| **Subbasin name** | Percent of cropped acres in Chesapeake Bay region | Acres | Percent of critical under-treated acres in Chesapeake Bay region | Percent of cropped acres in cropping system | Acres | Percent of under-treated acres in Chesapeake Bay region | Percent of cropped acres in cropping system |
| Corn-soybean only | 27 | 448,822 | 22 | 38 | 932,844 | 27 | 79 |
| Corn-soybean with close grown crops | 19 | 311,516 | 16 | 38 | 717,638 | 21 | 86 |
| Corn only | 16 | 437,371 | 22 | 63 | 592,289 | 17 | 86 |
| Hay-crop mix | 16 | 381,520 | 19 | 55 | 541,744 | 16 | 79 |
| Corn and close grown crops | 7 | 227,580 | 11 | 77 | 279,063 | 8 | 94 |
| Remaining mix of crops | 4 | 72,675 | 4 | 41 | 139,192 | 4 | 79 |
| Soybean only | 4 | 31,211 | 2 | 19 | 41,995 | 1 | 26 |
| Vegetable or tobacco with or without other crops | 3 | 49,872 | 2 | 36 | 136,606 | 4 | 98 |
| Soybean-wheat only | 3 | 43,267 | 2 | 35 | 83,703 | 2 | 67 |
| **Total** | 100 | 2,003,834 | 100 | 47 | 3,465,075 | 100 | 81 |

Note: Percents may not add to totals because of rounding.

# Chapter 7
# Assessment of Potential Gains from Further Conservation Treatment

Four conservation treatment scenarios were simulated to evaluate the potential gains from further conservation treatment in the Chesapeake Bay region:

- Treatment of the 2.0 million critical under-treated acres with water erosion control practices.
- Treatment of all 3.5 million under-treated acres with water erosion control practices.
- Treatment of the 2.0 million critical under-treated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.
- Treatment of all 3.5 million under-treated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.

The simulated levels of conservation treatment were designed to add the additional practices needed to complete the existing suite of practices so as to reduce sediment and nutrient losses at the edge of the field to acceptable levels. The existing practices were augmented with additional practices to—

- avoid or limit the potential for loss by using nutrient management practices (appropriate rate, timing, *and* method) on *all* crops in the rotation;
- control overland flow where needed; and
- trap materials leaving the field using appropriate edge-of-field mitigation where absent.

The simulated additional treatment consists of traditional conservation practices and treatment options that have been implemented over the past 10 years and would be expected to be found in current NRCS conservation plans.

The simulated treatment levels are intended to maintain the production capacity within the region to produce crops for food, fiber, forage, and fuel. The simulated practices produced small decreases in acres in crop production and crop yields.

The specific conservation practices used in the simulated treatments are not intended to be a prescription for how to construct conservation plans, but rather are a general representation of sets or suites of conservation practices that could be used to address multiple resource concerns. In actual planning situations a variety of alternative practice scenarios would be presented to the producer and selections would be based on the level of treatment need, cost of conservation implementation, impact on production goals, and preferences of the farm operator.

The level of conservation treatment is simulated to show potential environmental benefits, but is not designed to achieve specific environmental protection goals. Treatment scenarios were also not designed to represent actual program or policy options for the Chesapeake Bay region. Economic and programmatic aspects--such as producer costs, conservation program costs, and capacity to deliver the required technical assistance--were not considered in the design of the treatment scenarios.

Conservation crop rotations were not included in the treatment scenarios because of the criteria to maintain crop acres and preserve current market value and yield for the region. Nevertheless, crop rotations that are conducted specifically for the purpose of reducing average annual losses of sediment and nutrients from farm fields have a high potential to further improve crop nutrient efficiency and reduce contaminant loadings.

For the same reason, long-term conserving cover was not included in the treatment scenarios. Long-term conserving cover represents the ultimate conservation treatment for acres that are highly vulnerable to sediment and nutrient loss. Enrolling more cultivated cropland acres in programs that provide the economic incentives for long-term conserving cover may be necessary in some areas to meet watershed goals for environmental protection.

Pesticide management was also not addressed in the treatment scenarios. While erosion control practices influence pesticide loss, significant reductions in pesticide risk within the region will require more intensive Integrated Pest Management (IPM) practices, including pesticide substitutions. Simulation of additional IPM and any associated pesticide substitutions is site specific and requires more information about the sample fields than was available from the farmer survey.

## Simulation of Additional Water Erosion Control Practices

Erosion and surface water runoff treatment consists of structural and vegetative practices that slow runoff water and capture contaminants that it may carry. Practices were added where needed (summarized in table 45) according to the following rules.

- **In-field mitigation:**
  - Terraces were added to all sample points with slopes greater than 6 percent, and to those with slopes greater than 4 percent *and* a high potential for excessive runoff (hydrologic soil groups C or D). Although terraces may be too expensive or impractical to implement in all cases, they serve here as a surrogate for other practices that control surface water runoff.
  - Contouring or stripcropping was added to all other fields that did not already have those practices and did not have terraces.
  - Concentrated flow practices were not applied since they occur on unique landscape situations within the field; landscape data other than slope and slope length were not available for CEAP sample points.

- **Edge-of-field mitigation:**
  - Fields adjacent to water received a riparian buffer, if one was not already present.

- Fields not adjacent to water received a filter strip, if one was not already present.

In addition, the implementation of structural and vegetative practices is simulated by an adjustment in the land condition parameter used to estimate the NRCS Runoff Curve Number (RCN). The RCN is an empirical parameter used in surface hydrology for predicting direct runoff or infiltration. The hydrologic condition (a component in the determination of the RCN) was adjusted from "poor" to "good" for sample points where these additional practices were simulated.

Cover crops were not added. Similarly, tillage management was not altered in the simulation of conservation treatment.

## Simulation of Additional Nutrient Management Practices

The nutrient management treatment scenario consists of additional nutrient management practices where needed *in addition to* the water erosion control practices. The nutrient management practices simulated the application of nutrients at an appropriate rate, in an appropriate form, at appropriate times, and using an appropriate method to provide sufficient nutrients for crop growth while minimizing losses to the environment. Simulation of nutrient management required changes to nutrient applications for one or more crops on all but about 6 percent of the acres (see table 10).

### Specific rules for application timing

The goal for appropriate timing is to apply nutrients close to the time when the plant is likely to require them, thereby minimizing the opportunity for loss from the field. Rules for the timing of nutrient applications (both nitrogen and phosphorus) are:

- All commercial fertilizer applications were adjusted to 14 days prior to planting, except for acres susceptible to leaching loss.
- For acres susceptible to leaching loss (hydrologic soil group A, soils with sandy textures, or tile drained fields), nitrogen was applied in split applications, with 25 percent of the total application 14 days before planting and 75 percent 30 days after planting.
- Manure applications during winter months (December, January, February, and March) were moved to 14 days pre-plant or April 1, whichever occurs first. This rule allows for late March applications of manure in the warmer climates of the Chesapeake Bay region. April 1 is near the period when the soils warm and become biologically active. However, this late date could begin to pressure manure storage capacities and it is recognized that this could create storage problems.

In the baseline condition, about 20 percent of the cropped acres in the Chesapeake Bay region receive fertilizer applications in the fall for at least one spring-planted row crop in the rotation. The only fall application of nutrients simulated in the nutrient management treatment scenario was for fall seeded crops that received a starter fertilizer at planting time.

**Table 45**. Summary of additional structural practices simulated for under-treated acres to assess the potential for gains from additional conservation treatment in the Chesapeake Bay region

| | Critical under-treated acres | | Non-critical under-treated acres | | All under-treated acres | |
|---|---|---|---|---|---|---|
| Additional practice | Treated acres | Percent of total | Treated acres | Percent of total | Treated acres | Percent of total |
| Overland flow practice only | 5,143 | <1 | 41,971 | 3 | 47,115 | 1 |
| Terrace only | 19,744 | 1 | 33,247 | 2 | 52,990 | 2 |
| Filter only | 236,697 | 12 | 590,540 | 40 | 827,236 | 24 |
| Filter plus overland flow practice | 350,688 | 18 | 284,154 | 19 | 634,842 | 18 |
| Filter plus Terrace | 1,022,054 | 51 | 121,238 | 8 | 1,143,292 | 33 |
| Buffer only | 64,399 | 3 | 182,308 | 12 | 246,707 | 7 |
| Buffer plus overland flow practice | 112,168 | 6 | 84,640 | 6 | 196,808 | 6 |
| Buffer plus Terrace | 168,217 | 8 | 27,780 | 2 | 195,997 | 6 |
| One or more additional practices | 1,979,110 | 99 | 1,365,878 | 93 | 3,344,988 | 97 |
| No structural practices | 24,725 | 1 | 95,362 | 7 | 120,087 | 3 |
| Total | 2,003,834 | 100 | 1,461,240 | 100 | 3,465,075 | 100 |

Note: Percents may not add to totals because of rounding.

### Specific rules for method of application
If the method of application was other than incorporation then fertilizer and manure applications became incorporated. Incorporation reduces the opportunity for nutrients on the soil surface to be carried away in the soluble form or attached to eroding particles. For manure applications on no-till fields, if the manure had been broadcast applied it was changed to injected or placed under the soil surface. Manure of solid consistency was incorporated by disking without regard to the tillage management type. If the tillage type had been originally no-till, the incorporation of the manure changed the tillage type to mulch tillage.

### Specific rules for the form of application
If the tillage type was no-till, commercial fertilizer was changed to a form that could be knifed or injected below the soil surface. The change in form did not change the ammonia or nitrate ratio of the fertilizer. In some cases, incorporation of manure also required a change in the manure form to preserve the beneficial effects of tillage and residue management.

### Specific rules for the rate of nutrient applied
All nitrogen application rates for all crops were reduced to 1.2 times the crop removal rate. The 1.2 ratio is in the range of rates recommended by many of the Land Grant Universities. This rate replaces some of the environmental losses that occur during the cropping season, and also accounts for the savings in nutrients due to implementation of water erosion control practices.

For phosphorus, the application rates were adjusted to be equal to 1.1 times the amount of phosphorus removed in the crop at harvest over the crop rotation.

## Potential for Field-Level Gains

### Treatment of the 2.0 million critical under-treated acres
According to the model simulation, treatment of the 2.0 million most vulnerable under-treated acres with water erosion control practices would nearly eliminate sediment loss for these acres and dramatically reduce nitrogen and phosphorus lost to surface water, as shown in table 46.

Sediment loss would be reduced to an annual average of about 0.2 ton per acre per year for these acres, a 93-percent reduction. Nitrogen loss with surface runoff would be reduced to 3.0 pounds per acre per year on average (80-percent reduction), and phosphorus lost to surface water would be reduced to 2.5 pounds per acre per year (56-percent reduction). However, the re-routing of surface water to subsurface flow pathways would reduce nitrogen loss in subsurface flows by only 1 percent, on average, for these acres.

The addition of nutrient management had little additional effect on sediment loss or nitrogen loss with surface runoff, but was effective in reducing nitrogen loss in subsurface flows and phosphorus lost to surface water (table 46). Nitrogen loss in subsurface flows for these acres would be reduced 54 percent compared to losses simulated for the baseline conservation condition. Phosphorus lost to surface water would be reduced to an average loss of about 1.1 pounds per acre, representing a 80 percent reduction compared to the baseline condition for these acres.

These results support the conclusion drawn from the assessment of the effects of conservation practices that nutrient management practices need to be paired with erosion control practices to obtain net reductions in the loss of soluble nutrients.

Table 47 presents estimates of how treatment of only the 2.0 million most vulnerable acres in the region would reduce *overall* edge-of-field losses *for the region as a whole*. These results were obtained by combining treatment scenario model results for the 2.0 million acres with model results from the baseline conservation condition for the remaining acres. Treating the 2.0 million critical under-treated acres with soil erosion control practices *and* nutrient management practices would, for the region as a whole—

- reduce sediment loss in the region by 73 percent on average, compared to the baseline conservation condition;
- reduce total nitrogen loss by 35 percent:
    - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 58 percent, and
    - reduce nitrogen loss in subsurface flows by 33 percent;
- reduce phosphorus lost to surface water (sediment adsorbed and soluble) by 57 percent, and
- reduce environmental risk from loss of pesticide residues by about 8 to 11 percent.

**Table 46.** Conservation practice effects for additional treatment of 2.0 million critical under-treated acres in the Chesapeake Bay region

| | Baseline conservation condition | Treatment with erosion control practices | | Treatment with erosion control and nutrient management practices | |
|---|---|---|---|---|---|
| Model simulated outcome | Average annual amount | Average annual amount | Percent reduction | Average annual amount | Percent reduction |
| Water flow | | | | | |
| Surface water runoff (inches) | 4.2 | 3.4 | 20% | 3.4 | 20% |
| Subsurface water flow (inches) | 11.2 | 11.8 | -5% | 11.8 | -5% |
| Erosion and sediment loss | | | | | |
| Wind erosion (tons/acre) | 0.020 | 0.018 | 9% | 0.019 | 7% |
| Sheet and rill erosion (tons/acre) | 2.28 | 0.57 | 75% | 0.59 | 74% |
| Sediment loss at edge of field due to water erosion (tons/acre) | 2.43 | 0.17 | 93% | 0.17 | 93% |
| Soil organic carbon | | | | | |
| Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre) | -87 | 3 | -- | -15 | -- |
| Nitrogen | | | | | |
| Nitrogen applied (pounds/acre)* | 107 | 103 | 3% | 67 | 37% |
| Nitrogen in crop yield removed at harvest (pounds/acre) | 77 | 76 | 1% | 71 | 8% |
| Total nitrogen loss for all pathways except harvest (pounds/acre) | 67.9 | 55.4 | 18% | 28.2 | 58% |
| Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre) | 14.9 | 3.0 | 80% | 2.7 | 82% |
| Nitrogen loss in subsurface flows (pounds/acre) | 43.7 | 43.3 | 1% | 19.9 | 54% |
| Phosphorus | | | | | |
| Phosphorus applied (pounds/acre) | 29.7 | 29.0 | 2% | 17.7 | 40% |
| Total phosphorus loss for all pathways except harvest (pounds/acre) | 5.8 | 2.6 | 55% | 1.2 | 78% |
| Loss of phosphorus to surface water, including waterborne sediment (pounds/acre) | 5.7 | 2.5 | 56% | 1.1 | 80% |
| Pesticide loss | | | | | |
| Mass loss of pesticides for all pathways (grams of active ingredient/hectare) | 19.2 | 8.1 | 58% | 8.3 | 57% |
| Surface water pesticide risk indicator for aquatic ecosystem | 1.9 | 1.5 | 19% | 1.6 | 18% |
| Surface water pesticide risk indicator for humans | 0.4 | 0.3 | 17% | 0.3 | 15% |

* Total nitrogen applied was less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.

Note: Values reported in this table are for the 2.0 million critical under-treated acres only. Percent reductions are with respect to the baseline conservation condition.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

**Table 47.** Conservation practice effects for the region as a whole* after additional treatment of 2.0 million critical under-treated acres in the Chesapeake Bay region

| Model simulated outcome | Baseline conservation condition: Average annual amount | Treatment with erosion control practices: Average annual amount | Treatment with erosion control practices: Percent reduction | Treatment with erosion control and nutrient management practices: Average annual amount | Treatment with erosion control and nutrient management practices: Percent reduction |
|---|---|---|---|---|---|
| Water flow | | | | | |
| Surface water runoff (inches) | 4.5 | 4.1 | 9% | 4.1 | 9% |
| Subsurface water flow (inches) | 11.5 | 11.8 | -2% | 11.8 | -2% |
| Erosion and sediment loss | | | | | |
| Wind erosion (tons/acre) | 0.027 | 0.026 | 3% | 0.026 | 3% |
| Sheet and rill erosion (tons/acre) | 1.48 | 0.68 | 54% | 0.69 | 53% |
| Sediment loss at edge of field due to water erosion (tons/acre) | 1.44 | 0.38 | 74% | 0.38 | 73% |
| Soil organic carbon | | | | | |
| Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre) | -37 | 5 | -- | -3 | -- |
| Nitrogen | | | | | |
| Nitrogen applied (pounds/acre)** | 96 | 94 | 2% | 77 | 19% |
| Nitrogen in crop yield removed at harvest (pounds/acre) | 83 | 83 | 1% | 80 | 4% |
| Total nitrogen loss for all pathways except harvest (pounds/acre) | 52.6 | 46.8 | 11% | 34.0 | 35% |
| Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre) | 9.7 | 4.2 | 57% | 4.1 | 58% |
| Nitrogen loss in subsurface flows (pounds/acre) | 34.2 | 34.0 | 1% | 23.0 | 33% |
| Phosphorus | | | | | |
| Phosphorus applied (pounds/acre) | 25.1 | 24.7 | 1% | 19.5 | 22% |
| Total phosphorus loss for all pathways except harvest (pounds/acre) | 3.9 | 2.4 | 39% | 1.7 | 55% |
| Loss of phosphorus to surface water, including waterborne sediment (pounds/acre) | 3.7 | 2.3 | 40% | 1.6 | 57% |
| Pesticide loss | | | | | |
| Mass loss of pesticides for all pathways (grams of active ingredient/hectare) | 14.9 | 9.7 | 35% | 9.8 | 34% |
| Surface water pesticide risk indicator for aquatic ecosystem | 1.5 | 1.3 | 12% | 1.3 | 11% |
| Surface water pesticide risk indicator for humans | 0.3 | 0.3 | 9% | 0.3 | 8% |

* Results presented for the region as a whole combine model output for the 2.0 million treated acres with model results from the baseline conservation condition for the remaining acres.

** Total nitrogen applied was less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.

Note: Percent reductions are with respect to the baseline conservation condition.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

### Treatment of all 3.5 million under-treated acres.

Simulation of additional conservation treatment of all 3.5 million under-treated acres showed that, while per-acre sediment and nutrient loss reductions due to practices would be less on average than per-acre reductions for the 2.0 million most vulnerable under-treated acres, the percent reductions for the region as a whole at this level of treatment would be much higher.

Simulation results for only the 3.5 million under-treated acres are presented in table 48, and results for the region as a whole are presented in table 49. Treating all 3.5 million under-treated acres with soil erosion control practices *and* nutrient management practices would, for the region as a whole (table 49)—

- reduce sediment loss in the region by 86 percent on average, compared to the baseline conservation condition;
- reduce total nitrogen loss by 53 percent:
  - reduce nitrogen loss with surface runoff (sediment attached and soluble) by 73 percent, and
  - reduce nitrogen loss in subsurface flows by 52 percent;
- reduce phosphorus lost to surface water by 76 percent;
- reduce environmental risk from loss of pesticide residues by 11 to 13 percent.

### Comparison of treatment scenario results

The distributions of sediment and nutrient losses for the two levels of treatment are compared to the baseline conservation condition in the Chesapeake Bay region in figures 73-77. For perspective, the distribution of loss estimates if no conservation practices were in use, represented by the no-practice scenario, is also shown.

The distributions show how the number of acres with high losses could be reduced dramatically in the region, by treating the under-treated acres. For example, 23 percent of the acres in the Chesapeake Bay region exceed an annual average loss of sediment of 2 tons per acre per year in the baseline conservation condition. Model simulations suggest that treating the most vulnerable of the under-treated acres (2.0 million acres) with water erosion control practices would reduce the acres exceeding sediment loss of 2 tons per acre per year to 2 percent. Expanding the treatment to include all under-treated acres (3.5 million acres) would further reduce the acres exceeding annual sediment loss of 2 tons per acre to less than 1 percent.

Similar effects of additional treatment are shown for nitrogen lost with surface runoff and phosphorus lost to surface water. Treatment of critical under-treated acres with water erosion control *and* nutrient management would reduce the acres exceeding 15 pounds per acre of nitrogen lost to surface water to 2 percent (figure 75); treatment of all 3.5 million under-treated acres would nearly eliminate losses exceeding 15 pounds per acre. Acres exceeding 4 pounds per acre of phosphorus lost to surface water would be reduced to 10 percent by treating the critical acres and reduced to 3 percent by treating all under-treated acres.

For nitrogen loss in subsurface flow pathways, however, treatment of all 3.5 million under-treated acres would be required to reduce the overall regional edge-of-field losses to acceptable levels (figure 76). About 38 percent of the acres in the region have nitrogen loss in subsurface flows greater than 25 pounds per acre per year for the baseline conservation condition. This is in part the result of the use of soil erosion control practices with no or only partial use of nutrient management practices. Treating the 2.0 million critical under-treated acres with nutrient management practices would reduce this percentage to 25 percent. Treatment of all 3.5 million under-treated acres would reduce the percentage to 14 percent.

Soil organic carbon was minimally affected by the additional soil erosion control and nutrient management practices. Increases in soil organic carbon occur largely because of savings of carbon that would otherwise have been lost from the field through wind and water erosion. Figure 78 shows that the percentage of acres building soil organic carbon would increase from 40 percent for the baseline conservation condition to 49 percent with additional conservation treatment of the 3.5 million under-treated acres.

One of the objectives in constructing the treatment scenarios was to maintain the level of regional crop production. The removal of nitrogen at harvest serves as a useful proxy for crop yields and allows for aggregation over the mix of crops. The average annual amount of nitrogen removed at harvest was reduced about 9 percent for the 3.5 million acres treated with additional soil erosion control and nutrient management practices (table 48), which represents an 8-percent reduction for the region as a whole (table 49). Figure 79 shows that the distribution of nitrogen removed at harvest is slightly lower for the treatment scenarios but otherwise was similar to the distribution for the baseline conservation condition.

### Emerging technologies for reducing nitrogen loss from farm fields

The nutrient management treatment level simulated in this study represents feasible and proven conservation practices that are currently being successfully applied. There are, however, emerging conservation technologies that have the potential to further reduce nutrient loss from farm fields and provide even greater conservation benefits once the technologies become more widespread. These include—

- variable rate technology for precise nutrient application rates and placement methods;
- nitrogen use efficiency enhancers (time release and ammonia loss inhibitors);
- water control management that reduces late fall and early spring flushes of nitrate-laden drainage water; and
- constructed wetlands receiving surface water runoff from farm fields prior to discharge to streams and rivers.

New technologies that have the potential to increase crop yields without increasing nutrient inputs could further improve crop nutrient use efficiency and reduce offsite transport of nutrients relative to the level of crop production.

**Table 48**. Conservation practice effects for additional treatment of 3.5 million under-treated acres in the Chesapeake Bay region

| Model simulated outcome | Baseline conservation condition: Average annual amount | Treatment with erosion control practices: Average annual amount | Treatment with erosion control practices: Percent reduction | Treatment with erosion control and nutrient management practices: Average annual amount | Treatment with erosion control and nutrient management practices: Percent reduction |
|---|---|---|---|---|---|
| Water flow | | | | | |
| Surface water runoff (inches) | 4.4 | 3.6 | 20% | 3.6 | 20% |
| Subsurface water flow (inches) | 11.3 | 11.9 | -5% | 11.9 | -5% |
| Erosion and sediment loss | | | | | |
| Wind erosion (tons/acre) | 0.027 | 0.024 | 10% | 0.025 | 7% |
| Sheet and rill erosion (tons/acre) | 1.69 | 0.45 | 74% | 0.46 | 73% |
| Sediment loss at edge of field due to water erosion (tons/acre) | 1.67 | 0.14 | 92% | 0.14 | 92% |
| Soil organic carbon | | | | | |
| Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre) | -41 | 23 | -- | 4 | -- |
| Nitrogen | | | | | |
| Nitrogen applied (pounds/acre)* | 105 | 102 | 3% | 66 | 37% |
| Nitrogen in crop yield removed at harvest (pounds/acre) | 83 | 81 | 2% | 75 | 9% |
| Total nitrogen loss for all pathways except harvest (pounds/acre) | 60.0 | 51.0 | 15% | 25.3 | 58% |
| Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre) | 11.1 | 2.6 | 76% | 2.3 | 79% |
| Nitrogen loss in subsurface flows (pounds/acre) | 39.4 | 39.1 | 1% | 17.3 | 56% |
| Phosphorus | | | | | |
| Phosphorus applied (pounds/acre) | 27.5 | 26.9 | 2% | 16.5 | 40% |
| Total phosphorus loss for all pathways except harvest (pounds/acre) | 4.5 | 2.3 | 50% | 1.0 | 78% |
| Loss of phosphorus to surface water, including waterborne sediment (pounds/acre) | 4.4 | 2.1 | 51% | 0.9 | 79% |
| Pesticide loss | | | | | |
| Mass loss of pesticides for all pathways (grams of active ingredient/hectare) | 16.6 | 8.2 | 51% | 8.4 | 49% |
| Surface water pesticide risk indicator for aquatic ecosystem | 1.6 | 1.4 | 17% | 1.4 | 15% |
| Surface water pesticide risk indicator for humans | 0.4 | 0.3 | 15% | 0.3 | 12% |

* Total nitrogen applied was less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.
Note: Values reported in this table are for the 3.5 million under-treated acres only. Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

**Table 49**. Conservation practice effects for the region as a whole* after additional treatment of 3.5 million under-treated acres in the Chesapeake Bay region

| Model simulated outcome | Baseline conservation condition: Average annual amount | Treatment with erosion control practices: Average annual amount | Treatment with erosion control practices: Percent reduction | Treatment with erosion control and nutrient management practices: Average annual amount | Treatment with erosion control and nutrient management practices: Percent reduction |
|---|---|---|---|---|---|
| Water flow | | | | | |
| Surface water runoff (inches) | 4.5 | 3.8 | 16% | 3.8 | 16% |
| Subsurface water flow (inches) | 11.5 | 12.0 | -4% | 12.0 | -4% |
| Erosion and sediment loss | | | | | |
| Wind erosion (tons/acre) | 0.027 | 0.025 | 8% | 0.025 | 6% |
| Sheet and rill erosion (tons/acre) | 1.48 | 0.47 | 68% | 0.48 | 67% |
| Sediment loss at edge of field due to water erosion (tons/acre) | 1.44 | 0.19 | 87% | 0.20 | 86% |
| Soil organic carbon | | | | | |
| Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre) | -37 | 15 | -- | -1 | -- |
| Nitrogen | | | | | |
| Nitrogen applied (pounds/acre)** | 96 | 93 | 3% | 64 | 33% |
| Nitrogen in crop yield removed at harvest (pounds/acre) | 83 | 82 | 1% | 77 | 8% |
| Total nitrogen loss for all pathways except harvest (pounds/acre) | 52.6 | 45.3 | 14% | 24.5 | 53% |
| Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre) | 9.7 | 2.9 | 70% | 2.6 | 73% |
| Nitrogen loss in subsurface flows (pounds/acre) | 34.2 | 33.9 | 1% | 16.3 | 52% |
| Phosphorus | | | | | |
| Phosphorus applied (pounds/acre) | 25.1 | 24.6 | 2% | 16.2 | 35% |
| Total phosphorus loss for all pathways except harvest (pounds/acre) | 3.9 | 2.0 | 47% | 1.0 | 74% |
| Loss of phosphorus to surface water, including waterborne sediment (pounds/acre) | 3.7 | 1.9 | 49% | 0.9 | 76% |
| Pesticide loss | | | | | |
| Mass loss of pesticides for all pathways (grams of active ingredient/hectare) | 14.9 | 8.0 | 46% | 8.2 | 45% |
| Surface water pesticide risk indicator for aquatic ecosystem | 1.5 | 1.2 | 15% | 1.3 | 13% |
| Surface water pesticide risk indicator for humans | 0.3 | 0.3 | 13% | 0.3 | 11% |

* Results presented for the region as a whole combine model output for the 3.5 million treated acres with model results from the baseline conservation condition for the remaining acres.
** Total nitrogen applied was less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.
Note: Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

**Figure 73.** Estimates of average annual sediment loss for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Chesapeake Bay region

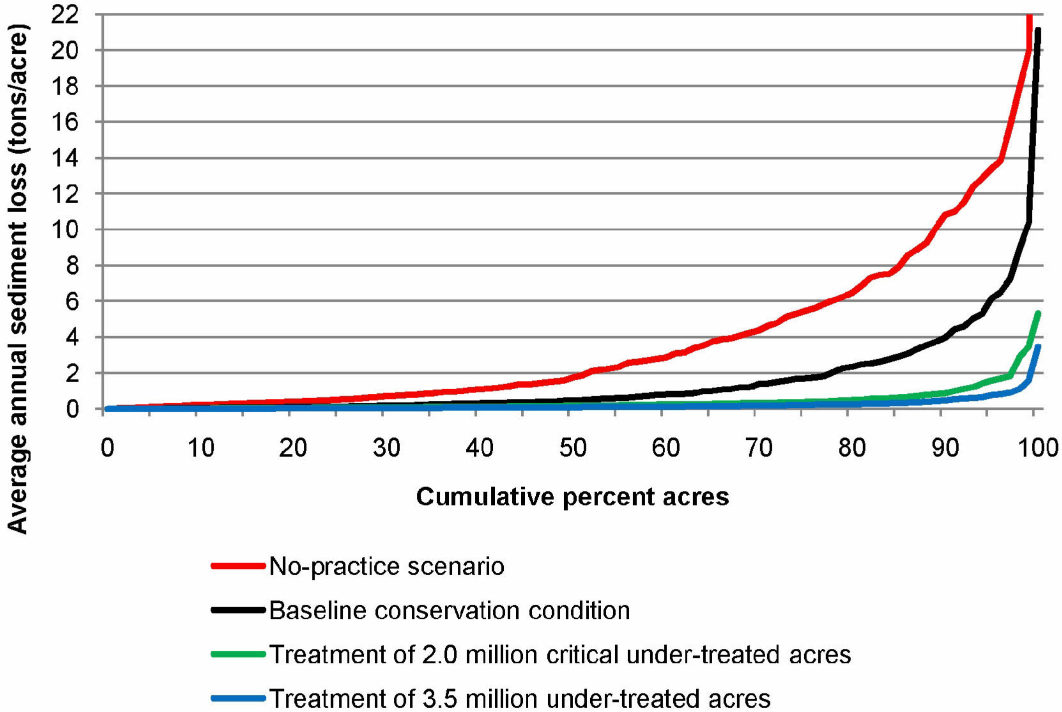



**Figure 74.** Estimates of average annual total nitrogen loss for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Chesapeake Bay region

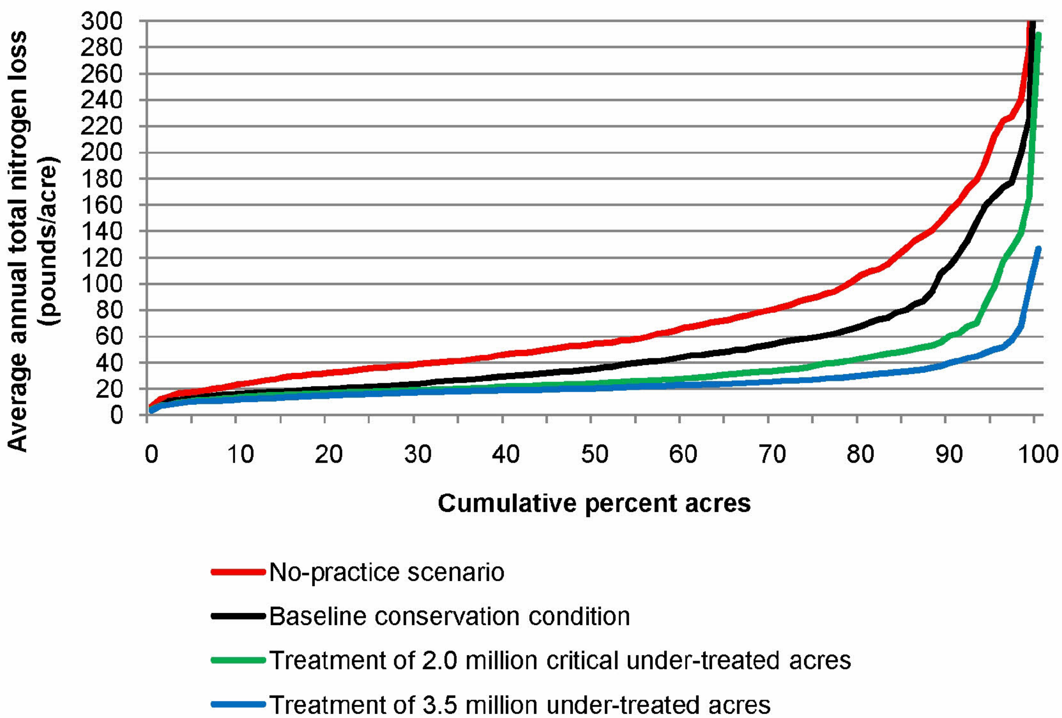


**Figure 75**. Estimates of average annual loss of nitrogen with surface runoff for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Chesapeake Bay region

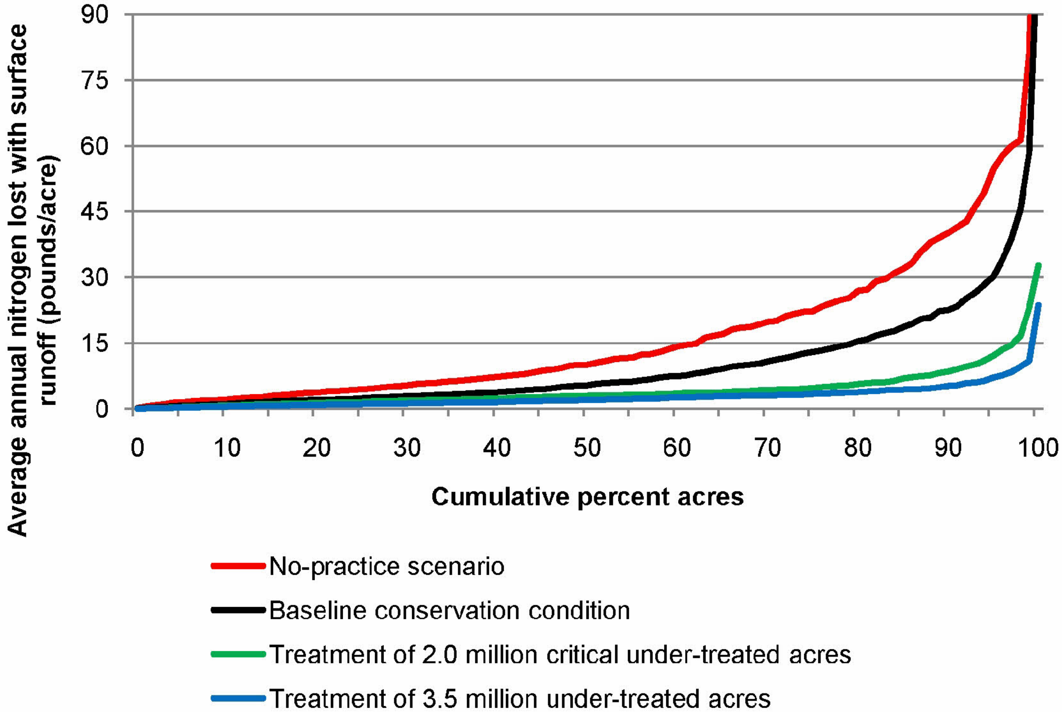



**Figure 76**. Estimates of average annual loss of nitrogen in subsurface flows for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Chesapeake Bay region

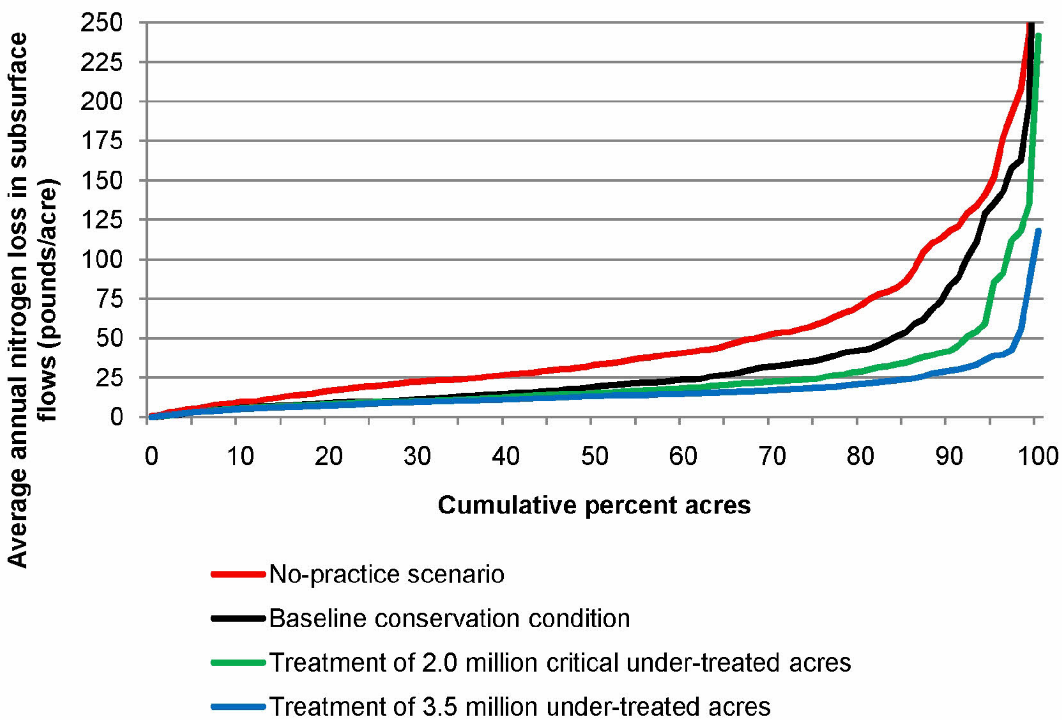
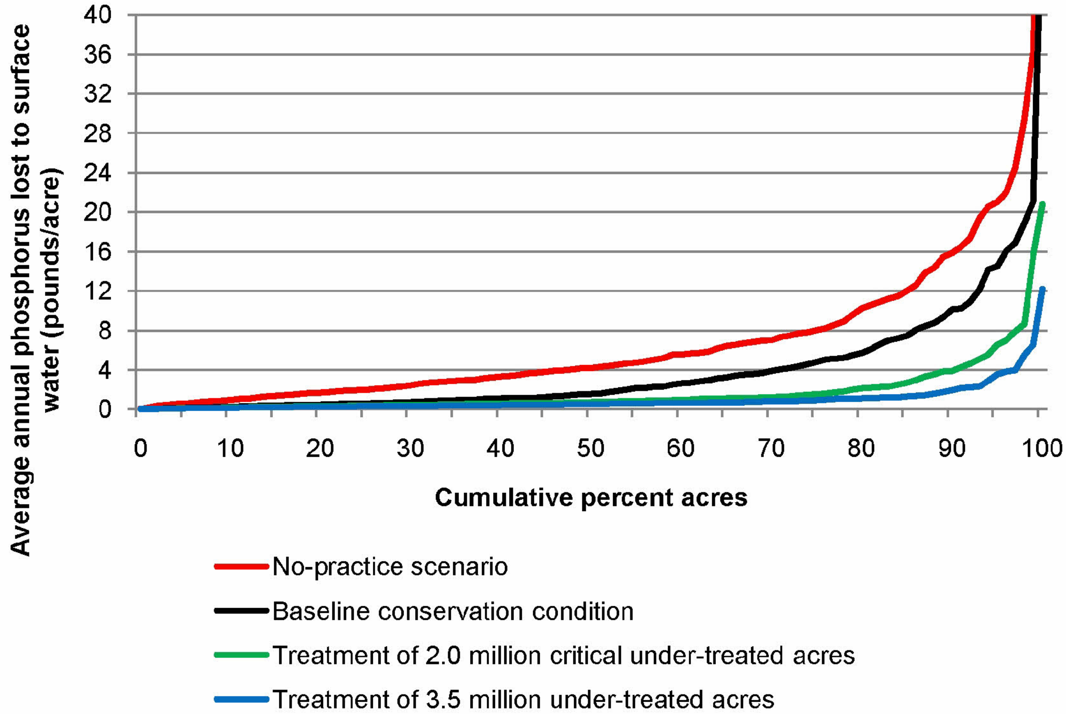


**Figure 77.** Estimates of average annual phosphorus lost to surface water (sediment attached and soluble)* for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Chesapeake Bay region




* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

**Figure 78.** Estimates of average annual change in soil organic carbon for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Chesapeake Bay region

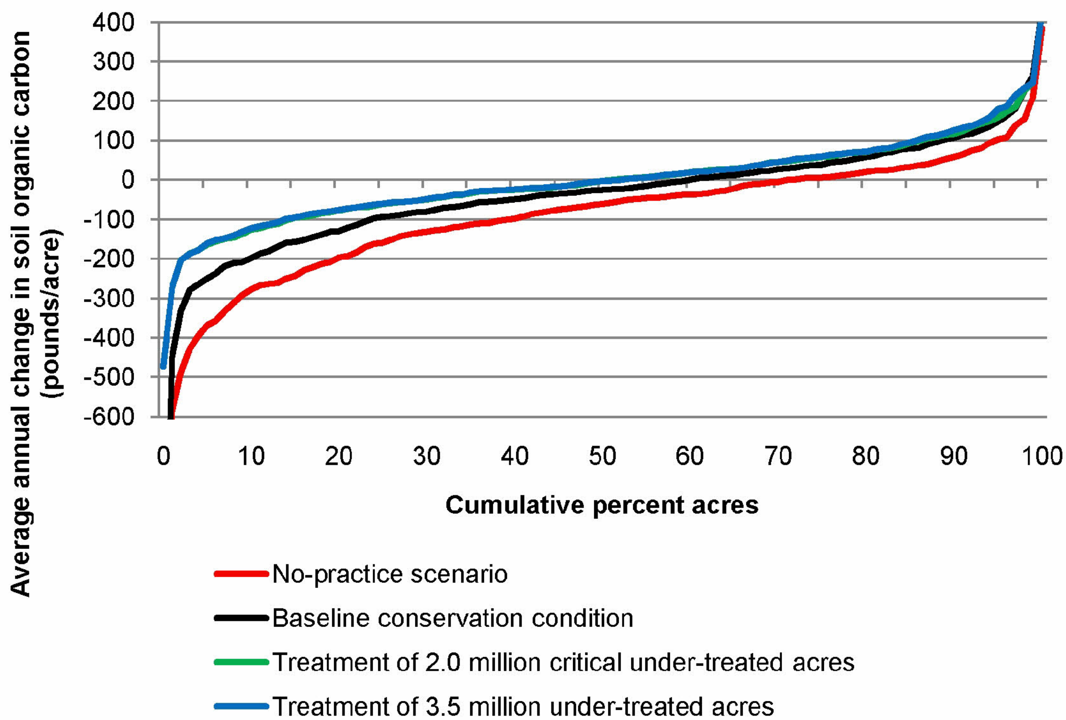
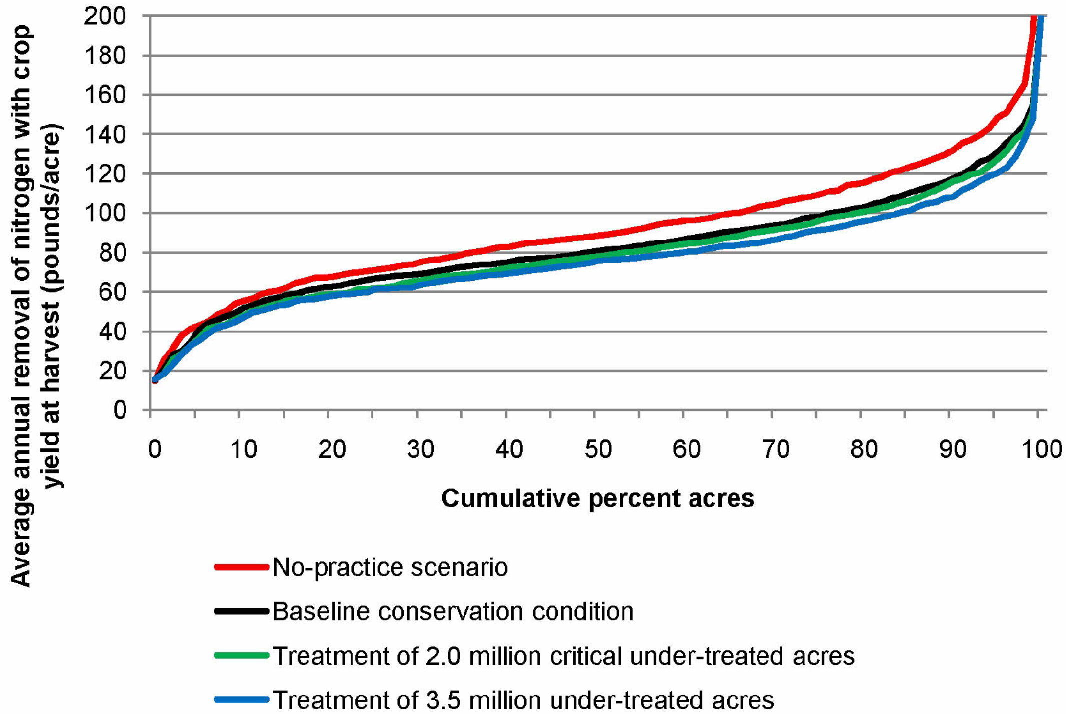


**Figure 79.** Estimates of average annual removal of nitrogen with crop yield at harvest for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Chesapeake Bay region



### Diminishing returns from additional conservation treatment.

Tables 46 through 49 and figures 73 through 77 suggest diminishing returns from additional conservation treatment when the most vulnerable acres are treated first. These diminishing returns are shown explicitly in table 50, which includes estimates of the effects of additional conservation practices on the 0.8 million adequately treated acres in the Chesapeake Bay region. Diminishing returns to additional conservation treatment is demonstrated by comparing the average annual per-acre reductions in loss among the three groups of acres.

For example, conservation treatment of the 2.0 million critical under-treated acres would reduce sediment loss an average of 2.3 tons per acre per year on those acres. In comparison, additional treatment of the remaining 1.5 million under-treated acres would reduce sediment loss by 0.5 ton per acre per year on those acres, and treatment of the remaining 0.8 million acres would reduce sediment loss by only 0.4 ton per acre per year on those acres, on average.

Similarly, diminishing returns were pronounced for nitrogen and phosphorus loss. Total nitrogen loss would be reduced by an average of 40 pounds per acre per year on the 2.0 million critical under-treated acres, compared to a reduction of 28 pounds per acre for the remaining 1.5 million under-treated acres and only 3 pounds per acre for the remaining 0.8 million acres. Total phosphorus loss would be reduced by an average of 4.5 pounds per acre per year on the 2.0 million critical under-treated acres, compared to a reduction of 2.1 pounds per acre for the remaining 1.5 million under-treated acres and only 0.5 pounds per acre for the remaining 0.8 million acres.

For nitrogen loss in subsurface flows, diminishing returns are not as evident until all the under-treated acres are treated because nitrogen leaching losses are pervasive throughout most of the region. Nitrogen loss in subsurface flows would be reduced by an average of 24 pounds per acre per year on the 2.0 million critical under-treated acres, compared to a reduction of 20 pounds per acre for the remaining 1.5 million under-treated acres. However, the reduction for treatment of the remaining 0.8 million acres would average only 0.3 pound per acre.

Diminishing returns for reduction in environmental risk for pesticides were not evident, primarily because pesticide risk was not taken into account in the identification of under-treated acres and the assessment of conservation treatment needs.

### Estimates of edge-of-field sediment and nutrient savings due to use of conservation practices

A convenient way to envision the potential gains from further conservation treatment is to contrast the potential sediment and nutrient savings to estimated savings for the conservation practices currently in use. The no-practice scenario represents losses without any conservation practices, and the treatment of *all* acres with nutrient management and water erosion control practices was used to represent a "full-treatment" condition. The difference in sediment and nutrient loss between these two scenarios was used to represent the maximum amount of savings possible for conservation treatment, which totaled 15.8 million tons of sediment, 109 thousand tons of nitrogen, and 12.6 thousand tons of phosphorus for the Chesapeake Bay region.

As shown in figure 80, about 65 percent of the potential sediment savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition. Additional treatment of the 2.0 million critical under-treated acres would account for another 29 percent of the potential sediment savings. Additional treatment of the remaining 1.5 million under-treated acres would account for about 5 percent of the potential savings. Further treatment of the 0.8 million adequately treated acres would account for the last 2 percent of potential savings.

For total phosphorus, 50 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition. Additional treatment of the 2.0 million critical under-treated acres would account for another 36 percent of the potential phosphorus savings. Additional treatment of the remaining 1.5 million under-treated acres would account for another 12 percent of the potential savings.

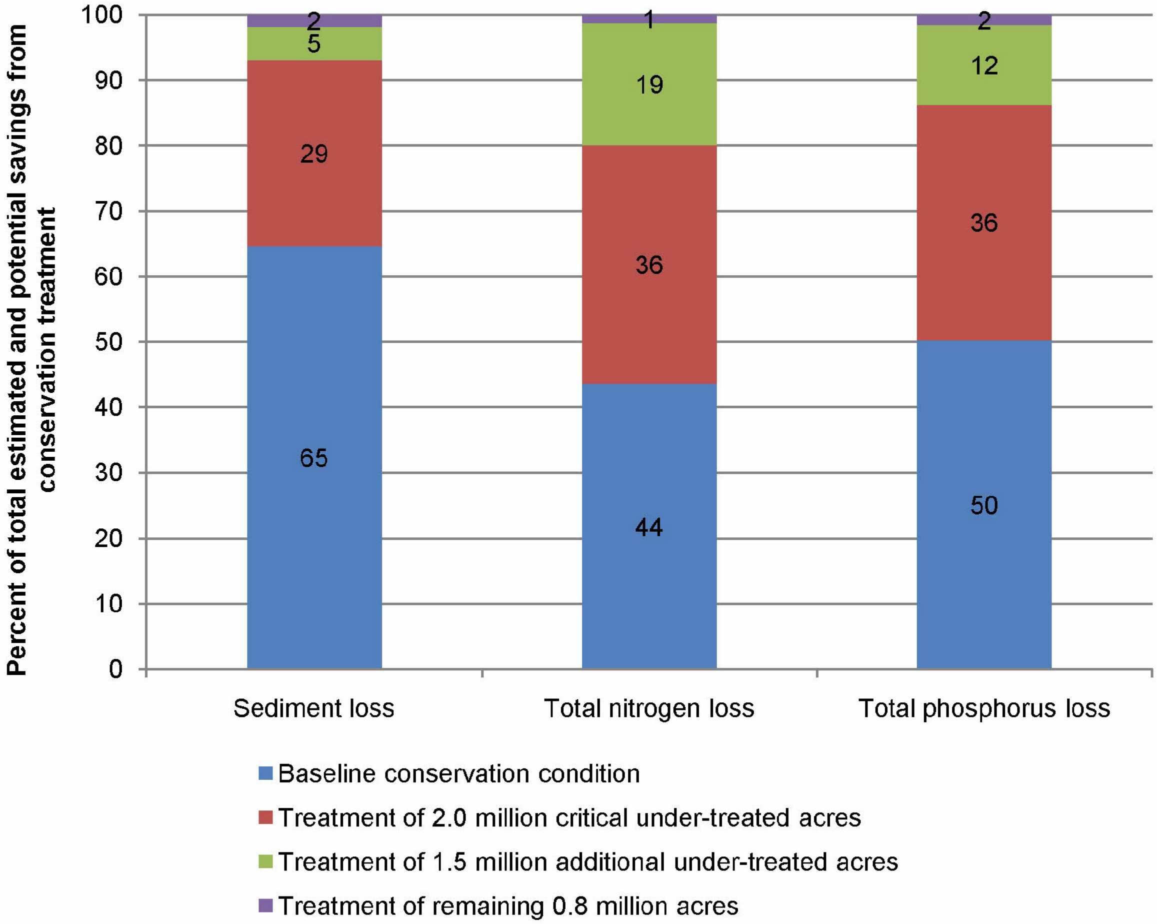
Less progress is evident for total nitrogen, and therefore the potential for savings with additional treatment is greater. The baseline conservation condition accounts for only 44 percent of the potential savings from conservation treatment. Treatment of the 2.0 million critical under-treated acres would account for an additional 36 percent of the potential nitrogen savings. Treatment of the remaining 1.5 million under-treated acres would account for another 19 percent of the potential nitrogen savings.

**Table 50** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices for three groups of acres comprising the 4.3 million cropped acres in the Chesapeake Bay region

| | Additional treatment for 2.0 million critical under-treated acres | | | Additional treatment for 1.5 million non-critical under-treated acres | | | Additional treatment for remaining 0.8 million acres | | |
|---|---|---|---|---|---|---|---|---|---|
| | Baseline | Treatment scenario | | Baseline | Treatment scenario | | Baseline | Treatment scenario | |
| | Average annual amount | Average annual amount | Reduction | Average annual amount | Average annual amount | Reduction | Average annual amount | Average annual amount | Reduction |
| Water flow | | | | | | | | | |
| Surface water runoff (inches) | 4.2 | 3.4 | 0.8 | 4.7 | 3.8 | 0.9 | 4.7 | 3.9 | 0.8 |
| Subsurface water flow (inches) | 11.2 | 11.8 | -0.6 | 11.3 | 12.0 | -0.6 | 12.6 | 13.2 | -0.6 |
| Erosion and sediment loss | | | | | | | | | |
| Wind erosion (tons/acre) | 0.020 | 0.019 | 0.001 | 0.037 | 0.035 | 0.002 | 0.025 | 0.023 | 0.002 |
| Sheet and rill erosion (tons/acre) | 2.28 | 0.59 | 1.69 | 0.89 | 0.29 | 0.61 | 0.58 | 0.20 | 0.37 |
| Sediment loss at edge of field due to water erosion (tons/acre) | 2.43 | 0.17 | 2.26 | 0.64 | 0.09 | 0.54 | 0.44 | 0.09 | 0.36 |
| Soil organic carbon | | | | | | | | | |
| Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre) | -87 | -15 | 72* | 22 | 29 | 7* | -19 | -1 | 17* |
| Nitrogen | | | | | | | | | |
| Nitrogen applied (pounds/acre) | 107 | 67 | 40 | 104 | 65 | 39 | 54 | 49 | 4 |
| Nitrogen in crop yield removed at harvest (pounds/acre) | 77 | 71 | 6 | 90 | 81 | 10 | 85 | 81 | 4 |
| Total nitrogen loss for all pathways except harvest (pounds/acre) | 67.9 | 28.2 | 39.7 | 49.2 | 21.3 | 27.8 | 21.2 | 17.9 | 3.4 |
| Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre) | 14.9 | 2.7 | 12.1 | 5.9 | 1.8 | 4.1 | 4.0 | 1.6 | 2.3 |
| Nitrogen loss in subsurface flows (pounds/acre) | 43.7 | 19.9 | 23.8 | 33.6 | 13.8 | 19.8 | 11.8 | 11.5 | 0.3 |
| Phosphorus | | | | | | | | | |
| Phosphorus applied (pounds/acre) | 29.7 | 17.7 | 11.9 | 24.4 | 14.9 | 9.5 | 14.9 | 13.0 | 2.0 |
| Total phosphorus loss for all pathways except harvest (pounds/acre) | 5.8 | 1.2 | 4.5 | 2.8 | 0.7 | 2.1 | 1.0 | 0.5 | 0.5 |
| Loss of phosphorus to surface water, including waterborne sediment (pounds/acre) | 5.7 | 1.1 | 4.5 | 2.7 | 0.6 | 2.1 | 0.9 | 0.4 | 0.5 |
| Pesticide loss | | | | | | | | | |
| Mass loss of pesticides for all pathways (grams of active ingredient/hectare) | 19.2 | 8.3 | 10.9 | 13.1 | 8.5 | 4.6 | 7.3 | 5.1 | 2.2 |
| Surface water pesticide risk indicator for aquatic ecosystem | 1.9 | 1.6 | 0.3 | 1.3 | 1.2 | 0.1 | 0.7 | 0.6 | 0.1 |
| Surface water pesticide risk indicator for humans | 0.4 | 0.3 | 0.1 | 0.3 | 0.3 | 0.0 | 0.2 | 0.2 | 0.0 |

* Gain in soil organic carbon.

**Figure 80.** Comparison of estimated sediment, nitrogen, and phosphorus savings that are due to practices in use in the baseline conservation condition and potential savings with additional water erosion control *and* nutrient management treatment of cropped acres in the Chesapeake Bay region




**Tons of sediment, nitrogen, and phosphorus saved or potentially saved due to conservation practices**

| | Estimated savings due to conservation practice use (baseline conservation condition) | Potential savings from treatment of 2.0 million critical under-treated acres* | Potential savings from treatment of 1.5 million non-critical under-treated acres* | Potential savings from treatment of remaining 0.8 million acres* | Total estimated and potential savings from conservation treatment |
|---|---|---|---|---|---|
| Sediment | 10,230,753 | 4,519,686 | 796,152 | 289,327 | 15,835,918 |
| Nitrogen | 47,597 | 39,795 | 20,344 | 1,367 | 109,103 |
| Phosphorus | 6,336 | 4,554 | 1,525 | 203 | 12,618 |

*Treatment with erosion control practices and nutrient management practices on all acres.
Note: Calculations exclude land in long-term conserving cover.

## Potential for Offsite Water Quality Gains

The field-level model results for the scenarios with additional erosion control practices *and* nutrient management were used with the HUMUS/SWAT model to determine the potential for further reductions in loads delivered from cultivated cropland to rivers and streams within the watershed and total loads delivered to the Bay (instream loads) with additional conservation treatment.

Percent reductions relative to the current conservation condition were estimated for each of two scenarios: (1) treatment of the 2.0 million critical under-treated acres, and (2) treatment of all 3.5 million under-treated acres, including the 2.0 million critical under-treated acres (tables 51 through 62). The distribution of under-treated acres within the Chesapeake Bay watershed is shown in chapter 6, table 43. The model simulations not only demonstrate the relative gains that can be expected from different levels of conservation effort but also provide insight into which subbasins are the most important in terms of reducing overall loads exported to the Bay. Figures 81 through 84 compare the baseline condition with the estimates of reductions in total loads (all sources) achievable under the two scenarios.

Model simulations showed that if the 2.0 million under-treated acres were fully treated with the appropriate soil erosion control and/or nutrient management practices, loads from cultivated cropland delivered to rivers and streams in the watershed would be reduced by, relative to the baseline conservation condition (tables 52, 55, 58, and 61)—

- 73 percent for sediment,
- 37 percent for nitrogen,
- 55 percent for phosphorus, and
- 12 percent for atrazine.

The largest reductions would occur in the Susquehanna River subbasin.

Model simulations further showed that if all of the under-treated acres (an additional 1.5 million acres) were fully treated with the appropriate soil erosion control and/or nutrient management practices, loads from cultivated cropland delivered to rivers and streams in the watershed would be reduced, relative to the baseline conservation condition (tables 52, 55, 58, and 61)—

- 84 percent for sediment,
- 53 percent for nitrogen,
- 71 percent for phosphorus, and
- 14 percent for atrazine.

These reductions in loads delivered to rivers and streams would also have a significant impact on the total loads from all sources delivered to the Bay. If all the critical under-treated acres (2.0 million acres) were fully treated with the appropriate soil erosion control and/or nutrient management practices, total loads delivered to the Bay would be reduced, relative to the baseline conservation condition (tables 53, 56, 59, 62 and figures 81-84)—

- 5 percent for sediment,
- 12 percent for nitrogen,
- 13 percent for phosphorus, and
- 10 percent for atrazine.

If *all* the under-treated acres (1.5 million additional acres) were fully treated with the appropriate soil erosion control and/or nutrient management practices, total loads delivered to the Bay would be reduced, relative to the baseline conservation condition (tables 53, 56, 59, 62 and figures 81-84)—

- 7 percent for sediment,
- 16 percent for nitrogen,
- 17 percent for phosphorus, and
- 11 percent for atrazine.

At this level of conservation treatment, sediment loads delivered to the Bay would be very close to the background level, indicating that contributions from cultivated cropland would be negligible. The background scenario represents loads that would be expected if no acres in the watershed were cultivated. For sediment, background loads total 6.34 million tons (table 25). Total loads delivered from all sources after treating all under-treated acres with appropriate erosion control practices would total 6.4 million tons (table 53), leaving less than 0.1 million tons originating from cultivated cropland.

At this level of conservation treatment, loads delivered to the Bay attributable to cultivated cropland would be about 40 million pounds for nitrogen and 1 million pounds for phosphorus (figures 82 and 83).

**Table 51.** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **sediment source loads** ***delivered to edge of field*** (APEX model output) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | Treatment of 2.0 million critical under-treated acres | | Treatment of all 3.5 million under-treated acres | |
|---|---|---|---|---|---|---|---|
| **8-digit HUC group*** | **Sub-basin code** | **Subbasin name** | Average annual load (1,000 tons) | Average annual load (1,000 tons) | Percent reduction | Average annual load (1,000 tons) | Percent reduction |
| I | 0205 | Susquehanna River | 4,852 | 828 | 83 | 551 | 89 |
| II | 0206 | Upper Chesapeake** | 675 | 454 | 33 | 209 | 69 |
| III | 0207 | Potomac River | 728 | 197 | 73 | 91 | 87 |
| IV + V | 0208 | Lower Chesapeake** | 387 | 145 | 63 | 72 | 81 |
| | | **Total** | 6,642 | 1,624 | 76 | 924 | 86 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Cultivated cropland acres used in HUMUS/SWAT modeling vary slightly from acre estimates based on the CEAP sample. Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 52.** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **sediment source loads** ***delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | Treatment of 2.0 million critical under-treated acres | | Treatment of all 3.5 million under-treated acres | |
|---|---|---|---|---|---|---|---|
| **8-digit HUC group*** | **Sub-basin code** | **Subbasin name** | Average annual load (1,000 tons) | Average annual load (1,000 tons) | Percent reduction | Average annual load (1,000 tons) | Percent reduction |
| I | 0205 | Susquehanna River | 1,696 | 324 | 81 | 228 | 87 |
| II | 0206 | Upper Chesapeake** | 265 | 186 | 30 | 90 | 66 |
| III | 0207 | Potomac River | 266 | 78 | 71 | 40 | 85 |
| IV + V | 0208 | Lower Chesapeake** | 155 | 62 | 60 | 33 | 79 |
| | | **Total** | 2,381 | 650 | 73 | 391 | 84 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 51 are due to the application of delivery ratios, which were used to simulate delivery of sediment from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 53.** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream sediment loads*** delivered to the Chesapeake Bay

| | | | Baseline conservation condition | Treatment of 2.0 million critical under-treated acres | | Treatment of all 3.5 million under-treated acres | |
|---|---|---|---|---|---|---|---|
| **Subbasin name** | **Sub-basin code** | **8-digit HUC group*** | Average annual load (1,000 tons) | Average annual load (1,000 tons) | Percent reduction | Average annual load (1,000 tons) | Percent reduction |
| Upper Chesapeake Bay | | | | | | | |
| Susquehanna River | 0205 | I | 1,441 | 1,315 | 9 | 1,298 | 10 |
| Upper Chesapeake | 0206 | II | 952 | 903 | 5 | 846 | 11 |
| Potomac River | 0207 | III | 2,392 | 2,280 | 5 | 2,257 | 6 |
| **Sub-total** | | | 4,785 | 4,498 | 6 | 4,401 | 8 |
| Lower Chesapeake Bay | | | | | | | |
| Rappahannock, York, and James Rivers | 0208 | IV | 2,034 | 1,987 | 2 | 1,970 | 3 |
| Eastern Shore | 0208 | V | 36 | 36 | 1 | 33 | 9 |
| **Sub-total** | | | 2,070 | 2,023 | 2 | 2,003 | 3 |
| **Total** | | | 6,855 | 6,521 | 5 | 6,404 | 7 |

*See figure 54.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

**Table 54.** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **nitrogen source loads** ***delivered to edge of field*** (APEX model output) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | Treatment of 2.0 million critical under-treated acres | | Treatment of all 3.5 million under-treated acres | |
|---|---|---|---|---|---|---|---|
| **8-digit HUC group*** | **Sub-basin code** | **Subbasin name** | Average annual load (1,000 pounds) | Average annual load (1,000 pounds) | Percent reduction | Average annual load (1,000 pounds) | Percent reduction |
| I | 0205 | Susquehanna River | 93,143 | 44,837 | 52 | 37,536 | 60 |
| II | 0206 | Upper Chesapeake** | 33,504 | 27,401 | 18 | 16,055 | 52 |
| III | 0207 | Potomac River | 20,013 | 11,479 | 43 | 8,318 | 58 |
| IV + V | 0208 | Lower Chesapeake** | 11,464 | 9,098 | 21 | 6,981 | 39 |
| | | **Total** | 158,120 | 92,815 | 41 | 68,890 | 56 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Cultivated cropland acres used in HUMUS/SWAT modeling vary slightly from acre estimates based on the CEAP sample.
*See figure 54. Some columns do not add to totals because of rounding.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 55.** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **nitrogen source loads** ***delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | Treatment of 2.0 million critical under-treated acres | | Treatment of all 3.5 million under-treated acres | |
|---|---|---|---|---|---|---|---|
| **8-digit HUC group*** | **Sub-basin code** | **Subbasin name** | Average annual load (1,000 pounds) | Average annual load (1,000 pounds) | Percent reduction | Average annual load (1,000 pounds) | Percent reduction |
| I | 0205 | Susquehanna River | 61,598 | 32,367 | 47 | 27,377 | 56 |
| II | 0206 | Upper Chesapeake** | 24,156 | 20,079 | 17 | 11,861 | 51 |
| III | 0207 | Potomac River | 13,513 | 8,288 | 39 | 6,130 | 55 |
| IV + V | 0208 | Lower Chesapeake** | 7,992 | 6,655 | 17 | 5,222 | 35 |
| | | **Total** | 107,260 | 67,389 | 37 | 50,590 | 53 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 54 are due to the application of delivery ratios, which were used to simulate delivery of nitrogen from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 56.** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream nitrogen loads*** delivered to the Chesapeake Bay

| | | | Baseline conservation condition | Treatment of 2.0 million critical under-treated acres | | Treatment of all 3.5 million under-treated acres | |
|---|---|---|---|---|---|---|---|
| **Subbasin name** | **Sub-basin code** | **8-digit HUC group*** | Average annual load (1,000 pounds) | Average annual load (1,000 pounds) | Percent reduction | Average annual load (1,000 pounds) | Percent reduction |
| Upper Chesapeake Bay | | | | | | | |
| Susquehanna River | 0205 | I | 128,280 | 101,100 | 21 | 96,917 | 24 |
| Upper Chesapeake | 0206 | II | 47,853 | 44,784 | 6 | 38,743 | 19 |
| Potomac River | 0207 | III | 81,261 | 75,787 | 7 | 73,570 | 9 |
| **Sub-total** | | | 257,394 | 221,671 | 14 | 209,230 | 19 |
| Lower Chesapeake Bay | | | | | | | |
| Rappahannock, York, and James Rivers | 0208 | IV | 55,195 | 53,930 | 2 | 52,751 | 4 |
| Eastern Shore | 0208 | V | 1,443 | 1,373 | 5 | 1,265 | 12 |
| **Sub-total** | | | 56,638 | 55,303 | 2 | 54,016 | 5 |
| **Total** | | | 314,032 | 276,974 | 12 | 263,246 | 16 |

*See figure 54.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

**Table 57.** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **phosphorus source loads** ***delivered to edge of field*** (APEX model output) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | Treatment of 2.0 million critical under-treated acres | | Treatment of all 3.5 million under-treated acres | |
|---|---|---|---|---|---|---|---|
| **8-digit HUC group*** | **Sub-basin code** | **Subbasin name** | Average annual load (1,000 pounds) | Average annual load (1,000 pounds) | Percent reduction | Average annual load (1,000 pounds) | Percent reduction |
| I | 0205 | Susquehanna River | 9,883 | 3,132 | 68 | 2,296 | 77 |
| II | 0206 | Upper Chesapeake** | 2,306 | 1,540 | 33 | 777 | 66 |
| III | 0207 | Potomac River | 2,989 | 1,226 | 59 | 750 | 75 |
| IV + V | 0208 | Lower Chesapeake** | 1,223 | 590 | 52 | 346 | 72 |
| | | **Total** | 16,400 | 6,489 | 60 | 4,168 | 75 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Cultivated cropland acres used in HUMUS/SWAT modeling vary slightly from acre estimates based on the CEAP sample. Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 58.** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **phosphorus source loads** ***delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | Treatment of 2.0 million critical under-treated acres | | Treatment of all 3.5 million under-treated acres | |
|---|---|---|---|---|---|---|---|
| **8-digit HUC group*** | **Sub-basin code** | **Subbasin name** | Average annual load (1,000 pounds) | Average annual load (1,000 pounds) | Percent reduction | Average annual load (1,000 pounds) | Percent reduction |
| I | 0205 | Susquehanna River | 3,529 | 1,313 | 63 | 990 | 72 |
| II | 0206 | Upper Chesapeake** | 973 | 671 | 31 | 335 | 66 |
| III | 0207 | Potomac River | 1,181 | 531 | 55 | 339 | 71 |
| IV + V | 0208 | Lower Chesapeake** | 511 | 261 | 49 | 156 | 70 |
| | | **Total** | 6,193 | 2,776 | 55 | 1,820 | 71 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 57 are due to the application of delivery ratios, which were used to simulate delivery of phosphorus from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 59.** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream phosphorus loads*** delivered to the Chesapeake Bay

| | | | Baseline conservation condition | Treatment of 2.0 million critical under-treated acres | | Treatment of all 3.5 million under-treated acres | |
|---|---|---|---|---|---|---|---|
| **Subbasin name** | **Sub-basin code** | **8-digit HUC group*** | Average annual load (1,000 pounds) | Average annual load (1,000 pounds) | Percent reduction | Average annual load (1,000 pounds) | Percent reduction |
| Upper Chesapeake Bay | | | | | | | |
| Susquehanna River | 0205 | I | 3,803 | 2,972 | 22 | 2,829 | 26 |
| Upper Chesapeake | 0206 | II | 2,234 | 1,957 | 12 | 1,725 | 23 |
| Potomac River | 0207 | III | 4,068 | 3,518 | 14 | 3,352 | 18 |
| **Sub-total** | | | 10,105 | 8,447 | 16 | 7,906 | 22 |
| Lower Chesapeake Bay | | | | | | | |
| Rappahannock, York, and James Rivers | 0208 | IV | 4,557 | 4,325 | 5 | 4,236 | 7 |
| Eastern Shore | 0208 | V | 87 | 87 | 0 | 80 | 9 |
| **Sub-total** | | | 4,644 | 4,412 | 5 | 4,315 | 7 |
| **Total** | | | 14,749 | 12,859 | 13 | 12,221 | 17 |

*See figure 54.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

**Table 60.** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **atrazine source loads** ***delivered to edge of field*** (APEX model output) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | Treatment of 2.0 million critical under-treated acres | | Treatment of all 3.5 million under-treated acres | |
|---|---|---|---|---|---|---|---|
| **8-digit HUC group*** | **Sub-basin code** | **Subbasin name** | Average annual load (1,000 pounds) | Average annual load (1,000 pounds) | Percent reduction | Average annual load (1,000 pounds) | Percent reduction |
| I | 0205 | Susquehanna River | 7.22 | 5.47 | 24 | 5.38 | 25 |
| II | 0206 | Upper Chesapeake** | 4.06 | 4.03 | 1 | 3.82 | 6 |
| III | 0207 | Potomac River | 2.48 | 2.21 | 11 | 2.20 | 11 |
| IV + V | 0208 | Lower Chesapeake** | 1.18 | 1.13 | 4 | 1.11 | 6 |
| | | **Total** | 14.93 | 12.84 | 14 | 12.52 | 16 |

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Cultivated cropland acres used in HUMUS/SWAT modeling vary slightly from acre estimates based on the CEAP sample. Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 61.** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **atrazine source loads** ***delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the 4 subbasins in the Chesapeake Bay watershed

| | | | Baseline conservation condition | Treatment of 2.0 million critical under-treated acres | | Treatment of all 3.5 million under-treated acres | |
|---|---|---|---|---|---|---|---|
| **8-digit HUC group*** | **Sub-basin code** | **Subbasin name** | Average annual load (1,000 pounds) | Average annual load (1,000 pounds) | Percent reduction | Average annual load (1,000 pounds) | Percent reduction |
| I | 0205 | Susquehanna River | 6.28 | 4.93 | 21 | 4.88 | 22 |
| II | 0206 | Upper Chesapeake** | 3.66 | 3.65 | 0 | 3.45 | 6 |
| III | 0207 | Potomac River | 2.18 | 1.99 | 9 | 2.00 | 8 |
| IV + V | 0208 | Lower Chesapeake** | 0.98 | 0.95 | 3 | 0.94 | 5 |
| | | **Total** | 13.10 | 11.52 | 12 | 11.27 | 14 |

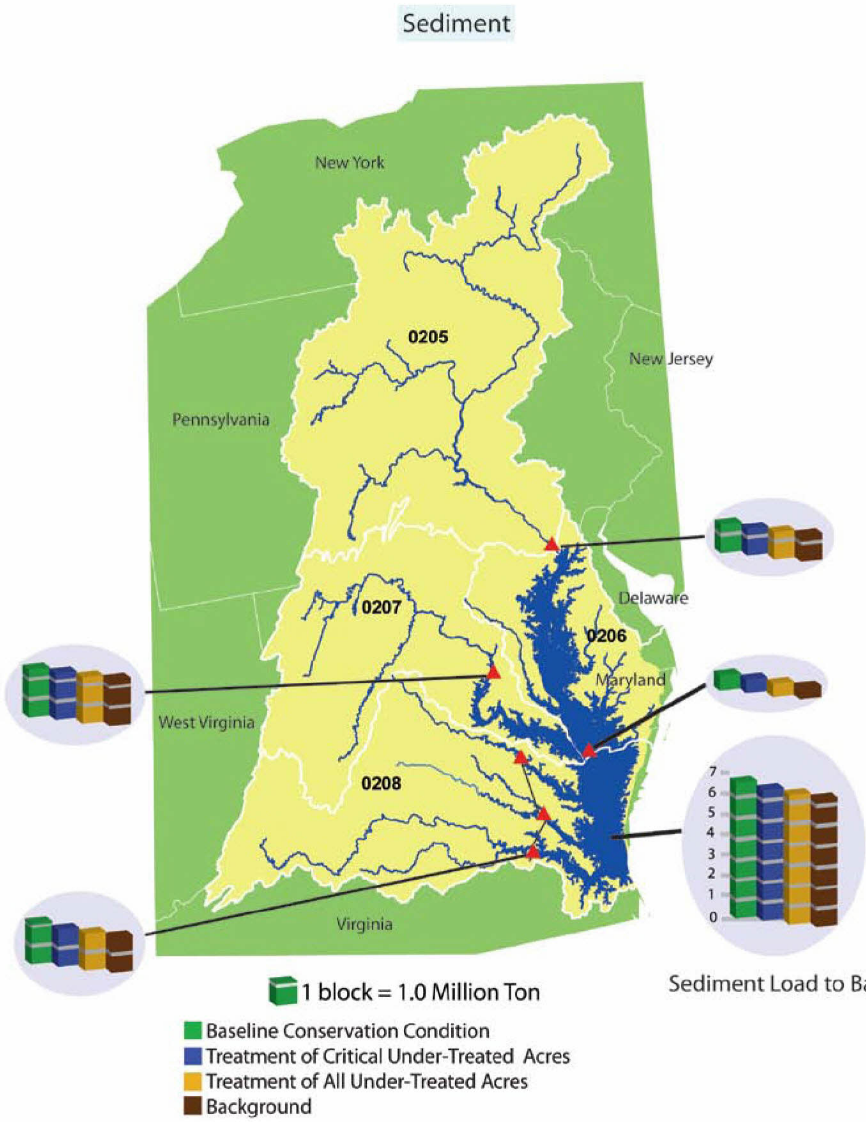
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 60 are due to the application of delivery ratios, which were used to simulate delivery of atrazine from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
*See figure 54.
**Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

**Table 62.** Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream atrazine loads*** delivered to the Chesapeake Bay

| | | | Baseline conservation condition | Treatment of 2.0 million critical under-treated acres | | Treatment of all 3.5 million under-treated acres | |
|---|---|---|---|---|---|---|---|
| **Subbasin name** | **Sub-basin code** | **8-digit HUC group*** | Average annual load (1,000 pounds) | Average annual load (1,000 pounds) | Percent reduction | Average annual load (1,000 pounds) | Percent reduction |
| Upper Chesapeake Bay | | | | | | | |
| Susquehanna River | 0205 | I | 3.86 | 3.13 | 19 | 3.10 | 20 |
| Upper Chesapeake | 0206 | II | 2.49 | 2.47 | 1 | 2.35 | 6 |
| Potomac River | 0207 | III | 1.86 | 1.73 | 7 | 1.77 | 5 |
| **Sub-total** | | | 8.20 | 7.33 | 11 | 7.21 | 12 |
| Lower Chesapeake Bay | | | | | | | |
| Rappahannock, York, and James Rivers | 0208 | IV | 0.82 | 0.80 | 2 | 0.80 | 3 |
| Eastern Shore | 0208 | V | 0.04 | 0.03 | 6 | 0.03 | 9 |
| **Sub-total** | | | 0.86 | 0.84 | 2 | 0.83 | 3 |
| **Total** | | | 9.06 | 8.17 | 10 | 8.04 | 11 |

*See figure 54.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

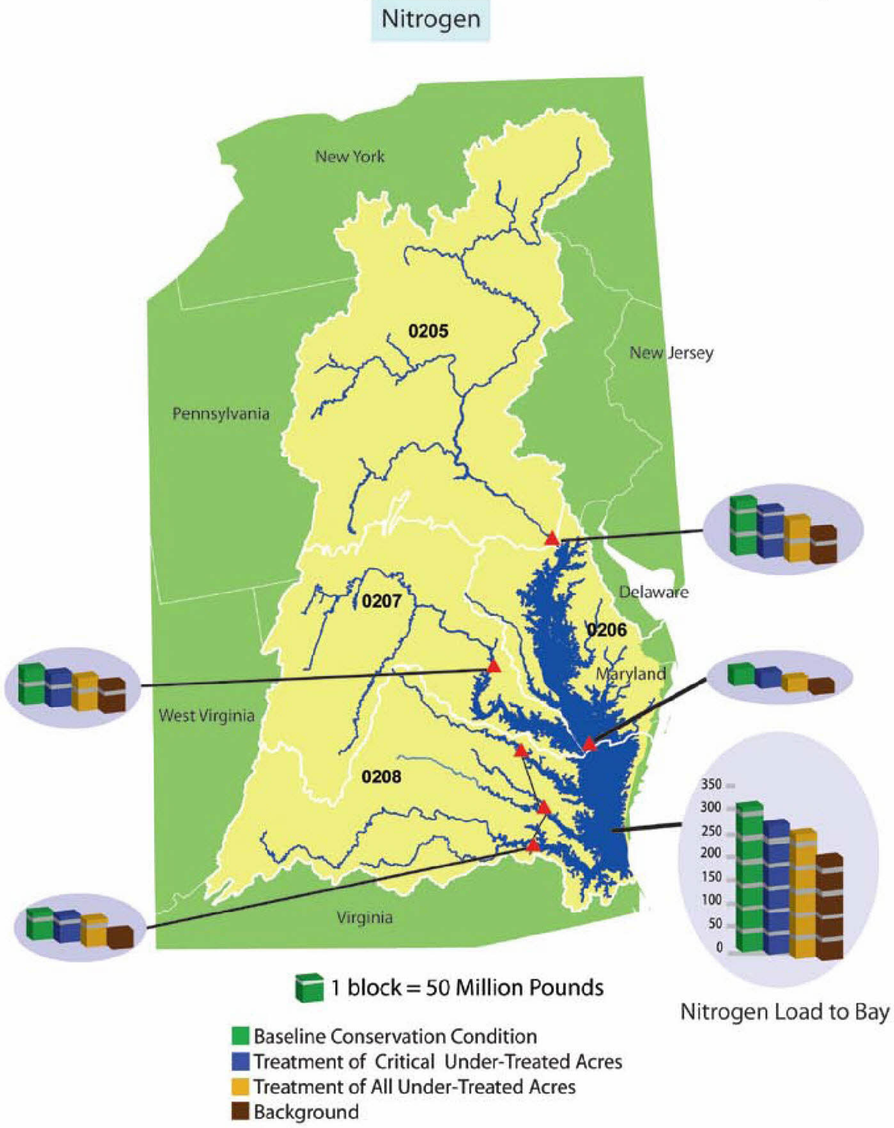
**Figure 81**. Estimates of average annual instream sediment loads* for the baseline conservation condition compared to two scenarios simulating additional water erosion control and nutrient management practices for subbasins in the Chesapeake Bay watershed




* Instream sediment loads delivered to the Chesapeake Bay (all sources) are shown for each of the four subbasins, corresponding to estimates presented in table 53. The total sediment load delivered to the Chesapeake Bay from all areas is shown in the bar chart in the lower right hand corner, labeled "Sediment load to Bay."

**Note**: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

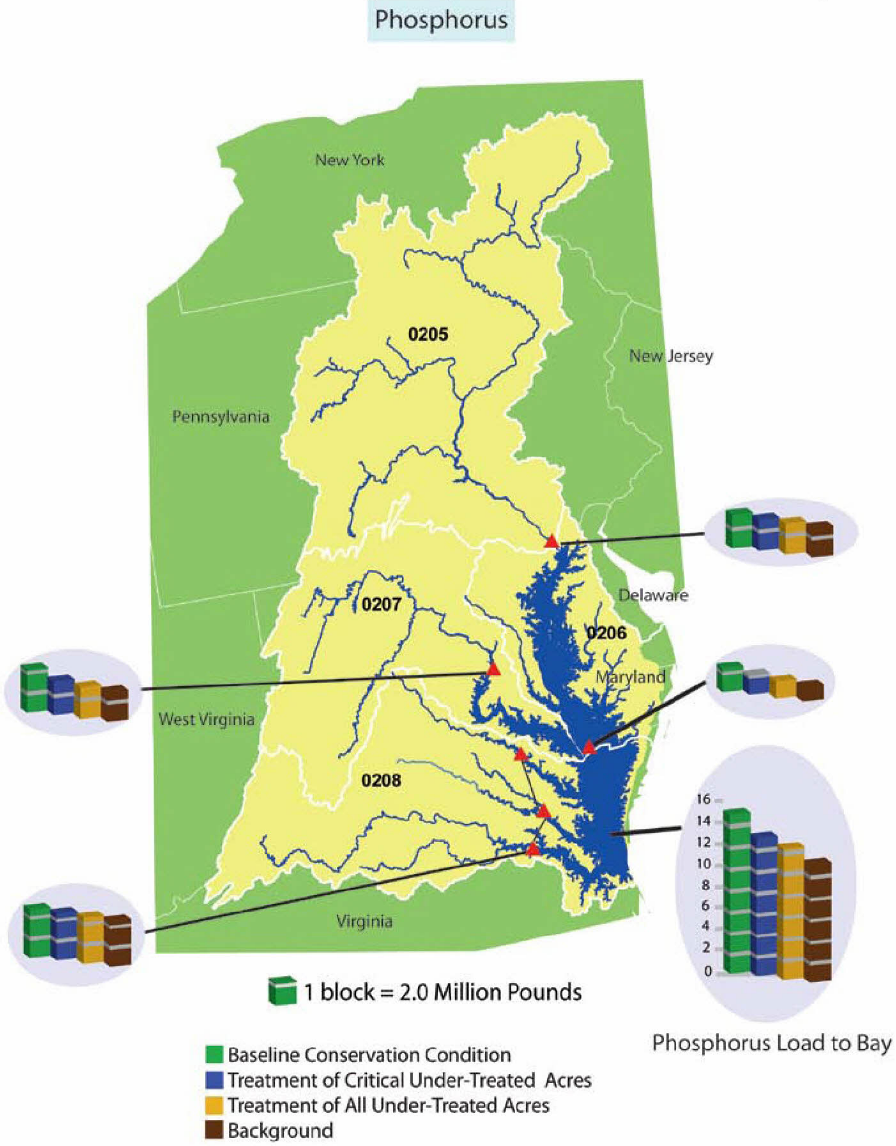
**Figure 82**. Estimates of average annual instream nitrogen loads* for the baseline conservation condition compared to two scenarios simulating additional water erosion control and nutrient management practices for subbasins in the Chesapeake Bay watershed




* Instream nitrogen loads delivered to the Chesapeake Bay (all sources) are shown for each of the four subbasins, corresponding to estimates presented in table 56. The total nitrogen load delivered to the Chesapeake Bay from all areas is shown in the bar chart in the lower right hand corner, labeled "Nitrogen load to Bay."

**Note**: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

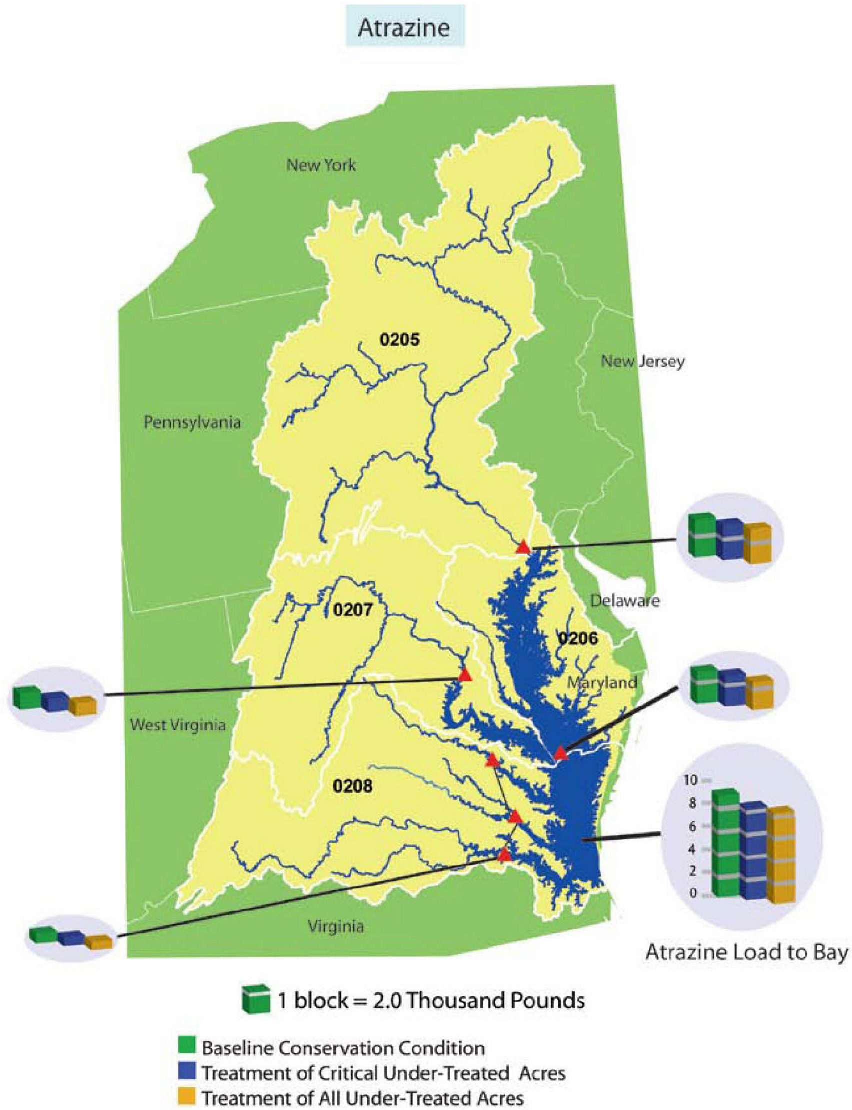
**Figure 83**. Estimates of average annual instream phosphorus loads* for the baseline conservation condition compared to two scenarios simulating additional water erosion control and nutrient management practices for subbasins in the Chesapeake Bay watershed




* Instream phosphorus loads delivered to the Chesapeake Bay (all sources) are shown for each of the four subbasins, corresponding to estimates presented in table 59. The total phosphorus load delivered to the Chesapeake Bay from all areas is shown in the bar chart in the lower right hand corner, labeled "Phosphorus load to Bay."

**Note**: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

**Figure 84**. Estimates of average annual instream atrazine loads* for the baseline conservation condition compared to two scenarios simulating additional water erosion control and nutrient management practices for subbasins in the Chesapeake Bay watershed




* Instream atrazine loads delivered to the Chesapeake Bay (all sources) are shown for each of the four subbasins, corresponding to estimates presented in table 62. The total atrazine load delivered to the Chesapeake Bay from all areas is shown in the bar chart in the lower right hand corner, labeled "Atrazine load to Bay."

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# Appendix A: Estimates of acres and standard errors

This appendix will consist of a table reporting estimated acres and the standard error for a collection of key variables included in the report.

# Appendix B
# Summary Tables of NRI-CEAP Cropland Survey Responses for the Chesapeake Bay Region

The NRI-CEAP Cropland Survey obtained information from farmers on field-level farming activities and conservation practices for a subset of National Resource Inventory (NRI) cultivated cropland sample points. The survey was specifically designed to obtain information needed as data inputs to the APEX physical process model.

The NRI-CEAP Cropland Survey collected information for all crops and for multiple years, thereby providing a landscape representation of the cropping systems present. A cropping system represents a suite of crops typically grown in a crop rotation along with the field operations and chemical use associated with that suite of crops.

Because of annual financial constraints as well as the logistics of data collection, the data collection process was spread over the 4-year period 2003 through 2006. In each year, a separate set of sample points was selected. The final CEAP sample was constructed by pooling the set of usable, completed surveys from all 4 years. The results therefore represent farming activities from 2003 through 2006.

Survey questionnaire responses are summarized in this appendix for the CEAP samples in the Chesapeake Bay region. These results reflect what was reported in the survey and do not include adjustments that were necessary to conduct the physical process modeling.[27] Because the samples were drawn from an area sample frame, all data summaries are in terms of acres.[28]

## Survey Data Collection

The National Agricultural Statistics Service (NASS) administered the survey with assistance from FSA and NRCS. NASS, the agency that has the authority to conduct public surveys for USDA, has the staff, infrastructure, and experience to implement large survey efforts of this nature. The survey was conducted in two phases.

### Phase I

The names and addresses of the operators of the fields associated with the sample point locations were obtained in Phase I. The collection of the name and address information provided (1) a contact for providing the operator with survey publicity materials encouraging cooperation, and (2) an initial contact for field enumeration to begin the second phase.

Prior to data collection, NRCS provided NASS field enumerators with aerial photographs and county maps showing the locations of the CEAP sample sites. NRCS combined NRI digital location information with digital county base map products to plot CEAP sample point locations. County maps include roads, towns, hydrographic features, and other information for locating the general vicinity of the sample point. To identify the field associated with the CEAP sample point, an ortho-rectified (scale accurate) aerial photograph was provided showing the location of the sample point.

Phase I data collection occurred in June and July. In 2003 and 2004, NASS enumerators visited Farm Service Agency (FSA) field offices and, using the county maps and aerial photographs provided by NRCS, worked with FSA staff to determine the identity of the farm operator. Once the point had been visibly located on FSA photography, the FSA farm field and tract number information were extracted and recorded. FSA databases were then accessed to provide the name and contact information for the farm operator, as well as information on Conservation Reserve Program (CRP) signups. For sample points that fell on farming operations that did not participate in USDA programs, county plat maps or other types of county records were consulted to determine the farm operator.

In 2005 and 2006, an alternative technology and approach was used to identify farm operators. This approach used the digitized data on field boundaries referred to as the Common Land Unit (CLU), or FSA CLU data layer, which allowed many of the farm operator names and much of the contact information to be obtained through a digital merge process. In this process, NRI digital point location information was merged with CLU data to determine the FSA field and tract number. The field and tract number was then used to extract the name of the farm operator and other pertinent program information from FSA databases.

Prospective respondents received an advance letter and information brochure informing them that they had been selected and that a NASS enumerator would be contacting them to ask about their operation of a selected field. The brochure explained the purpose of the survey and encouraged participation.

### Phase II

The CEAP questionnaire was designed to be enumerated as a personal interview with the operator who made the day-to-day operating decisions. Participation in the survey was voluntary, and all data collected are confidential. In addition to the personal interview, NASS enumerators visited the NRCS field offices to obtain additional information about conservation program participation and the content of conservation plans. Data collection was conducted typically from September through December. Following data collection, NASS assembled the survey responses into a database. Edit checks were conducted to identify questionable survey responses and, where necessary, to follow up with the respondent to clear up discrepancies.

Prior to the start of the fall data collection, State survey administrators conducted workshops at the local level to

[27] See the documentation report "Transforming Survey Data to APEX Model Input Files" at http://www.nrcs.usda.gov/technical/nri/ceap/cropland.html.

[28] An area sample frame was used so that the results would represent conditions on the landscape. Representation of results in terms of enterprises or farms, rather than acres, is incompatible with the area sample frame.

familiarize field enumerators with the questionnaire, techniques for obtaining successful interviews, and educating enumerators on common practices found in their State. The State workshops ranged from 1.5 to 2.5 days. Training methods included section-by-section review of the questionnaire and identification of data relationships between sections.

An established protocol for enumerating, handling, and editing questionnaires was enacted once data collection began. At the start of data collection, field enumerators located and interviewed the respondents. If the initial contact was not the day-to-day decision maker, enumerators identified and located the correct respondent and conducted the interview. If three attempts to locate the respondent during the survey data collection period failed, the enumerator coded the questionnaire as “inaccessible.”

Because participation in the CEAP Survey was voluntary, respondents had the option to decline the interview. Some respondents cooperated reluctantly and although they provided responses to some questions, declined to complete sections of the questionnaire that required more detailed information Incomplete surveys were not used for simulation modeling.

When beginning the interview, a screening process was used to determine if the NRI-CEAP point met the required definition of cultivated cropland. If a crop was planted or cropped for production, or if the cropland was idled, in summer fallow, or pasture in rotation with crops, the sample was considered usable for survey purposes and the entire questionnaire was enumerated. If the sample did not meet these criteria, the interview was concluded and the sample points were considered to be out-of-scope.

-- tables summarizing results from the survey will follow.

# Appendix C: Model Simulation Results for the Baseline Conservation Condition for the 4 Subbasins in the Chesapeake Bay Region

Model simulation results presented in Chapter 4 for the baseline conservation condition are presented in tables C-1 and C-2 for the 4 subbasins in the Chesapeake Bay region.

The column headings refer to the subbasin code. The names of the subbasins are shown below:

| Sub-basin code | Subbasin name |
|---|---|
| 0205 | Susquehanna River |
| 0206 | Upper Chesapeake |
| 0207 | Potomac River |
| 0208 | Lower Chesapeake |

**Table C-1**. Average annual estimates of water flow, erosion, and soil organic carbon for the baseline conservation condition for cropped acres, by subbasin, in the Chesapeake Bay region

| Model simulated outcome | Chesapeake Bay region | 0205 | 0206 | 0207 | 0208 |
|---|---|---|---|---|---|
| **Cropped acres (million acres)** | 4,279,900 | 1,734,800 | 1,187,900 | 684,000 | 673,200 |
| Percent of acres in region | 100% | 41% | 28% | 16% | 16% |
| Percent of acres irrigated | 5% | 1% | 12% | 1% | 6% |
| Percent of acres receiving manure | 38% | 53% | 34% | 43% | 1% |
| **Water sources (average annual inches)** | | | | | |
| Non-irrigated acres | | | | | |
| Precipitation | 42 | 41 | 44 | 41 | 44 |
| Irrigated acres | | | | | |
| Precipitation | 43 | 38 | 44 | 40 | 41 |
| Irrigation water applied | 13 | 10 | 14 | 10 | 11 |
| **Water loss pathways (average annual inches)** | | | | | |
| Evapotranspiration | 27.6 | 26.6 | 28.0 | 27.9 | 29.0 |
| Surface water runoff | 4.5 | 4.5 | 4.8 | 3.9 | 4.5 |
| Subsurface water flow | 11.5 | 10.4 | 13.7 | 9.1 | 13.2 |
| **Erosion and sediment loss (average annual tons/acre)** | | | | | |
| Wind erosion | 0.03 | 0.02 | 0.04 | 0.01 | 0.05 |
| Sheet and rill erosion | 1.48 | 2.35 | 0.65 | 1.57 | 0.60 |
| Sediment loss at edge of field due to water erosion | 1.44 | 2.45 | 0.51 | 1.37 | 0.54 |
| **Soil organic carbon (average annual pounds/acre)** | | | | | |
| Loss of soil organic carbon with wind and water erosion | 162 | 209 | 118 | 165 | 118 |
| Change in soil organic carbon, including loss of carbon with wind and water erosion | -37 | -85 | -14 | 10 | -1 |

**Table C-2**. Average annual estimates of nitrogen loss, phosphorus loss, and pesticide loss for the baseline conservation condition for cropped acres, by subbasin, in the Chesapeake Bay region

| Model simulated outcome | Chesapeake Bay region | 0205 | 0206 | 0207 | 0208 |
|---|---|---|---|---|---|
| **Nitrogen (average annual pounds/acre)** | | | | | |
| Nitrogen sources | | | | | |
| Atmospheric deposition | 8.7 | 9.7 | 7.5 | 8.5 | 8.6 |
| Bio-fixation by legumes | 26.3 | 18.4 | 34.4 | 22.6 | 36.3 |
| Nitrogen applied as commercial fertilizer and manure | 95.6 | 102.7 | 87.5 | 105.6 | 81.4 |
| All nitrogen sources | 130.7 | 130.8 | 129.5 | 136.7 | 126.3 |
| Nitrogen loss pathways | | | | | |
| Nitrogen in crop yield removed at harvest | 83.1 | 73.1 | 90.7 | 84.2 | 94.4 |
| Nitrogen loss by volatilization | 6.9 | 5.8 | 7.4 | 8.2 | 7.6 |
| Nitrogen loss through denitrification processes | 1.6 | 2.0 | 1.0 | 2.0 | 1.5 |
| Nitrogen lost with windborne sediment | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 |
| Nitrogen loss with surface runoff , including waterborne sediment | 9.7 | 14.7 | 5.1 | 10.0 | 5.0 |
| Nitrogen loss in subsurface flow pathways | 34.2 | 44.2 | 28.1 | 33.3 | 20.2 |
| Total nitrogen loss for all pathways except harvest | 52.6 | 66.8 | 41.8 | 53.5 | 34.5 |
| Change in soil nitrogen | -6.3 | -10.9 | -3.7 | -2.2 | -3.3 |
| **Phosphorus (average annual pounds/acre)** | | | | | |
| Phosphorus applied as commercial fertilizer and manure | 25.1 | 29.4 | 18.9 | 31.4 | 18.6 |
| Phosphorus loss pathways | | | | | |
| Phosphorus in crop yield removed at harvest | 13.1 | 11.8 | 14.0 | 13.5 | 14.7 |
| Phosphorus lost with windborne sediment | 0.03 | 0.02 | 0.04 | 0.03 | 0.04 |
| Phosphorus lost to surface runoff, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage ditches | 3.75 | 5.39 | 1.79 | 4.98 | 1.71 |
| Soluble phosphorus loss to groundwater | 0.07 | 0.08 | 0.07 | 0.07 | 0.07 |
| Total phosphorus loss for all pathways except harvest | 3.85 | 5.50 | 1.91 | 5.07 | 1.82 |
| Change in soil phosphorus | 8.05 | 12.01 | 2.93 | 12.77 | 2.09 |
| **Pesticides** | | | | | |
| Average annual amount of pesticides applied (grams of active ingredient/hectare) | 2000 | 1733 | 2061 | 2178 | 2397 |
| Pesticide loss | | | | | |
| Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare) | 15 | 16 | 14 | 18 | 11 |
| Edge-of-field pesticide risk indicator | | | | | |
| Average annual surface water pesticide risk indicator for aquatic ecosystem | 1.5 | 1.6 | 1.3 | 1.8 | 1.1 |
| Average annual surface water pesticide risk indicator for humans | 0.3 | 0.3 | 0.4 | 0.5 | 0.2 |
| Average annual groundwater pesticide risk indicator for humans | 0.3 | 0.3 | 0.4 | 0.5 | 0.2 |